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ON THE SPECTRA OF STARS OF CLASS III *b*.

By N. C. Dunér.

In the beginning of the year 1893 the Upsala Observatory came into possession of a new double refractor, provided with a Steinheil visual objective of 36 cm aperture and a photographic objective, also by Steinheil, of 33 cm aperture. The mounting is a very perfect one by Repsold. From the first I had planned to reëxamine the stars of the III class. On the one hand it was to be expected that with this instrument, the light-gathering power of which is considerably greater than that of the Lund refractor, more details would be visible in the spectra; while on the other hand, eight years had already passed since the publication of my memoir, "Sur les étoiles à spectres de la troisième classe," during which time many new stars belonging to class III had been discovered, and it seemed to me desirable that so far as possible all such stars in the northern heavens should be examined by one and the same observer. In this investigation, as well as in all other work with the refractor, serious interruptions occurred, partly because the summer nights here are as light as day, partly on account of the almost invariably bad and unfavorable weather of Upsala winters, and partly also because

of other causes, one of which, my rather poor health during recent winters, has unfortunately had an ever increasing effect. As a consequence this investigation, while well advanced in several hours of right ascension, still contains serious omissions in hours 2–8, 16–18 and 20.

Furthermore, since the greatest telescopes in the world have entered this field, it can hardly be of further interest to continue these investigations in a climate so unsuitable as that of Upsala for astronomical observations. But since in the course of the observations already made certain new details have been discovered in the spectra of stars of class III *b*, and since these confirm the results published by Professor Hale in the ASTROPHYSICAL JOURNAL, Vol. VIII, No. 4, I beg leave to present them here.

Four spectroscopes, all of the Zöllner type, have been employed in my observations. The first three belong to a set made by O. Toepfer, of Potsdam, and the direct-vision prisms have the following dispersions (C — G):

I	3° 23′
II	5° 1′
III	6° 56′

Spectroscope IV was made after my own indications by G. Rose, of Upsala, and contains a Steinheil direct-vision prism giving a dispersion of 10° between the same limits. These spectroscopes can be attached to the lowest eyepiece of the refractor, and in good atmospheric conditions give very beautiful spectra. For the greater part of the spectra of type III *b* the spectroscope designated as Ss III was found to be best adapted; for very faint objects Ss I was most suitable. For the most brilliant spectra Ss IV occasionally performed admirably.

As for the designations of the stars I need only remark that by "Birm." is meant the *second* edition, published by Espin, of Birmingham's Catalogue of Red Stars. The colors of the stars, the spectra, and the spectral bands, are designated in exactly the same manner as in my memoir "Sur les étoiles à spectres de la troisième classe."

An examination of the following list of my observations of spectra of type III *b* will show that my hopes of seeing more with the Upsala refractor than with the Lund refractor were not disappointed. Of first importance is the fact that I was able to detect without difficulty bright lines in various spectra, which at Lund were either invisible or at least could not be discovered. But it has also been possible for me here to determine with far greater ease and certainty the nature of several other spectra, among which mention may be made of the extremely interesting objects 280 *Schj.* and R S Cygni.

3 SCHJ. = 4 BIRM. = BD. + 43°53 (8.2^m).

Rrrg = 9.0. Sp. III *b!!* 3 bright zones, the blue one extremely faint and hardly visible. Band 6 strong. The yellow subzone bright, bands 4 and 5 well seen. Bands 2 and 3 suspected on one occasion. (Ss I 93.9.18, 93.10.5, 93.10.29, 92.10.30, 93.10.31, 93.11.3, 97.11.1. Ss III 95.9.27, 95.10.11, 97.11.1.)

10 BIRM. = BD. + 34°56 (8.1^m).

Rrg = 8.2. Sp. III *b!!* 3 bright zones, the blue one not particularly faint. The yellow subzone is well marked. Bands 6 and 9 are broad and very strong, 5 fairly strong, 4 clearly visible, 3 rather faint, 2 very faint. (Ss I 93.10.15, 93.10.30, 93.10.31, 93.11.5. Ss III 95.10.11, 95.10.24, 96.9.29, 96.10.6.)

13 BIRM. = W CASSIOPEIAE (VAR.).

Rrrg = 8.8. Sp. III *b* with 2 zones. Band 6 broad. (Ss I 93.10.15, 93.10.30, 93.10.31, 93.11.5, 95.10.24, 95.11.15. Ss III 95.10.24, 95.11.15.)

7 SCHJ. = 19 BIRM. = BD. + 25°205 (7.1^m).

Rrg = 8.0. Sp. III *b!!!* 4 zones, of which the ultra-blue is rather faint. Bands 9 and 10 strong and broad, 6 narrow, not brighter than 4; 4 is rather broad, clearly visible, and sharply bounded. Band 5 is fainter than 4, but broad, dim; 2, 3, 8 are faint. (Ss I 93.10.15, 93.10.22, 93.10.30, 93.10.31, 93.11.5.

Ss III 95.9.27, 95.10.11, 95.10.24, 96.1.5, 96.1.11. Ss IV 96.9.18.)

29 BIRM. = BD. + 57°325 (9.2^m).

Rrrg = 8.9. Sp. III *b!* The spectrum is extremely faint with 2 zones. Band 6 broad and dark. (Ss I 93.10.30, 95.11.15, 96.10.11. Ss III 95.11.15, 96.1.11.)

X CASSIOPEIAE (VAR.).

Rrrg = 9.1. Sp. III *b*. 2 zones. Band 6 broad, strong. (Ss I 93.11.5, 95.10.24, 96.9.29. Ss III 95.10.24, 96.9.29.)

42 BIRM. = BD. + 51°575 (9.0^m).

Rrrg = 9.0. Sp. III *b !* 2 zones. Band 6 very broad and dark. (Ss I 95.10.11. Ss III 95.10.11.)

64 BIRM. = BD. + 57°702 (7.9^m).

Rrg = 8.1. Sp. III *b!!!* 4 zones, 3 of which are very bright, while the ultra-blue one is quite faint. The principal bands extremely broad and black, 5 rather strong, 4 clearly visible, 3 and particularly 2, faint. (Ss I 93.10.30, 93.10.31, 93.11.8, 94.2.3, 96.1.11, 96.1.20. Ss III 93.12.1, 95.11.15, 96.1.11, 96.1.20, 96.1.26.)

66 BIRM. = BD. + 47°783 (9.0^m).

Rrg = 8.6. Sp. III *b!* 3 zones, of which the green is the brightest. Bands broad but dim. (Ss I 93.10.31, 93.11.8, 94.2.3, 96.1.5. Ss III 96.1.5.)

27*a* SCHJ. = 75 BIRM. = U CAMELOPARDI (VAR.).

Rrg = 8.7. Sp. III *b!!* 3 zones, the blue one very faint. Band 9 very broad and strong, 6 fainter, 4 and 5 rather strong, 3 and particularly 2, faint. (Ss I 93.10.22, 93.10.31, 93.11.8, 95.10.24. Ss. III 95.10.24.)

81 BIRM. = BD. + 61°667 (7.0^m).

Rrg = 7.8. Sp. III *b!!* 4 zones, the ultra-blue one quite faint. Bands 9 and 10 very strong and broad, 6 fainter. The yellow subzone not strong. Band 5 is broad, 4 clearly visible, 2 and 3 faint. (Ss I 93.10.31, 93.12.28.)

41 SCHJ. = 97 BIRM. = 67° 350 (7.0^m).

Rrg = 8.8. Sp. III *b!!!* 4 zones, the ultra-blue one faint. The yellow subzone very bright, particularly in the less refrangible half. Bands 9, 10 and 6 very broad and strong, 5 broad and strong, 4 rather strong, 8 clearly visible, 2, 3, 7 faint. (Ss I 93.4.23, 93.12.28. Ss III 93.12.28.)

45 SCHJ. = 105 BIRM. = 5 W ORIONIS (VAR.).

Rrg = 8.8. Sp. III*b !!!* 3 zones, the blue one rather faint. On November 19, 1895, I thought I detected a very faint trace of an ultra-blue zone. The yellow subzone is very bright. Band 9 very strong, 6 strong, and contains a *bright* line. Band 5 strong, apparently double, 4 and 3 rather strong, 2, 8 rather faint. (Ss I 93.11.23, 95.11.19, 96.1.26. Ss III 96.1.26.)

BD. + 38° 1035 (8.5^m).

Rrg = 8.2. Sp. III *b!!* 3 zones, the green one the brightest, the blue one somewhat faint. On one occasion the yellow subzone was seen conspicuously. Bands 9 and 6 are strong. Espin's star *BD.* = + 38° 1038 is undoubtedly identical with this one. (Ss I, Ss. III 94.2.22, 95.10.24, 96.1.6, 96.1.11.)

BIRM. 125 = BD. + 35° 1046 (8.9^m).

Rrg = 8.2. Sp. III *b!* 3 zones. Band 9 strong, 6 rather dull. (Ss I, Ss III 96.1.9, 96.1.11.)

72 SCHJ. = 172 BIRM. = BD. + 26° 1117 (7.4^m).

Rrg = 8.3. Sp. III *b !!* 3 zones and perhaps also an ultra-blue one. Band 9 very strong, 6 not strong. Bands 5, 4 quite strong, 3 well seen, 2 faint. (Ss I, Ss III 94.2.3, 97.2.10.)

74 SCHJ. = 187 BIRM. = BD. + 14° 1283 (6.5^m).

Rrg = 8.3. Sp. III *b!!!* 4 zones, the ultra-blue one quite faint. Bands 9 and 10 strong, broad, 6 remarkably faint, fainter than 5. 4 stronger than 5; 3, 2 well seen. (Ss I, Ss III 93.11.23, 94.2.3).

78 SCHJ. = 192 BIRM. = BD. + 38°1539 (6.3^m).

Rrg = 8.0. Sp. III *b!!!!* 4 zones, all of them bright; the yellow subzone extraordinarily bright. Bands 9, 10 extremely strong and broad, 6 is fainter, but strong; in this band is a hair-like, clearly visible, *bright* line. Band 5 is double; the less refrangible component is the fainter. Band 4 is broad, strong and sharply bounded, 1 quite broad and distinct, 2 rather broad and strong, 3 narrow, but rather dark. The distance from 2 to 3 is greater than that from 3 to 4, but 2 is shaded toward the violet, so that 3 is in the middle of the red subzone; 7, 8 are easily seen and between them there is a faint line. (Ss I 93.11.23, 94.2.2, 94.2.3. Ss II 93.3.1, 93.11.23, 94.2.3. Ss III 93.11.23, 94.1.4, 94.2.2, 94.2.3, 95.3.18, 96.1.9, 96.1.11, 97.2.10. Ss IV 97.2.23, 97.2.24.)

BD. + 31°1388 (8.1^m).

Rrg = 8.0. Sp. III *b!!* 3 zones, all of them bright. Bands 9 and 6 very dark. The yellow subzone rather bright. Bands 4 and 5 suspected on one occasion. (Ss I, Ss III 96.1.23.)

225 BIRM. = BD. + 25° 1641 (9.0^m).

Rrg = 7.8. Sp. III *b!!* 3 zones, all of them bright, and perhaps an exceedingly faint trace of an ultra-violet zone. The yellow subzone is not especially bright; the extreme end of the green zone, on the contrary, is very exceptionally bright. Bands 9 and 6 are very broad and strong; 5, 4, 8 occasionally visible. (Ss I 94.2.3, 94.2.5, 96.1.23. Ss II 94.2.5. Ss III 94.2.3, 94.2.5, 96.1.23.)

235 BIRM. = BD. + 24°1686 (8.2^m).

Rg = 7.3. Sp. III *b!!* with 4 zones, the ultra-blue one remarkably faint and hardly visible, while the blue one is very bright. Band 9 is quite strong; 6, on the contrary, is very faint. The yellow subzone is no brighter than the rest of the spectrum. (Ss I, Ss III 96.1.20, 96.1.23, 97.2.28.)

264*a* BIRM. = BD. + 3° 1958 (8.3^m).

Rrg = 8.3. Sp. III *b!!* with two bright and one extremely faint blue zone. Band 6 is broad and strong. (Ss I, Ss III 94.2.5, 97.2.28.)

115 SCHJ. = 211 BIRM. = BD. + 17° 1973 (6.5^m).

Rrg = 8.7 Sp. III *b!!!!* with 4 zones, the ultra-blue one faint. Bands 9 and 10 are exceedingly broad and dark, 6 somewhat narrower and fainter, with *bright* lines. The yellow subzone is very bright. Band 5 strong, double, 4 rather strong, 3 well seen, 8, 2 faint. (Ss I 94.2.3, 94.2.5, 94.3.24, 96.3.20. Ss II 94.2.3. Ss III 94.2.3, 94.2.5, 94.3.24, 96.3.20, 96.4.2, 97.2.24.)

318 BIRM. = BD. + 68° 617 (6.2^m).

Rrg = 8.2. Sp. III *b!!!!* 4 zones, the ultra-blue one quite bright. Bands 9 and 10 exceedingly broad and dark. 6 is relatively faint but contains *bright* lines. 5 is broad, strong and distinctly double, 4 strong, 3 sharply terminated, not faint, 2 relatively strong, 1, 7 faint, 8 well seen. On one occasion a band was suspected far out in the ultra-blue zone. (Ss I 94.3.22. Ss II 93.4.1, 96.4.4. Ss III 94.3.22, 94.3.25, 95.4.14, 96.3.30, 96.4.2, 96.4.4.)

145 SCHJ. = 350 BIRM. = BD. + 1° 2694 (8.1^m).

Rrg = 8.8. Sp. III *b!!* 3 zones, the blue one not especially faint. The yellow subzone exceptionally faint. Bands 9, 6 strong, 5 rather strong, 4 easily visible, 3 and perhaps also 2 faintly visible. (Ss I, Ss III 94.3.25, 95.4.15, 95.4.17, 95.4.26, 95.5.1. Ss II 95.5.1.)

152 SCHJ. = 364 BIRM. = BD. + 46° 1817 (5.5^m).

Rrg = 8.2. Sp. III *b!!!!* Remarkably beautiful, with 3 very bright and one rather faint ultra-blue zone. The more refrangible half of the yellow subzone is very bright, while the less refrangible half appears veiled. The principal bands, 9, 10 and 6 are exceedingly broad and strong; in 6 near the yellow sub-

zone there is a fine, brilliant *bright* line. Band 5 consists of two rather broad components, the more refrangible of which falls in the middle of the subzone. Half-way between this and band 6 is a fine, rather faint line. Band 8 is rather strong, 4 quite strong, 3 somewhat stronger than 4; 7 and 2 are faint. (Ss I 95.4.14. Ss II 95.4.14. Ss III 94.3.25, 95.4.14, 95.4.15, 95.4.30, 95.5.1, 95.5.2, 95.5.4, 96 4.2. Ss III 97.2.28, 97.4.26.)

155*b* SCHJ. = 374 BIRM. = BD. 66° 780 (7.5^m).

Rrg = 8.4. Sp. III *b!!!* 4 zones, the ultra-blue one very faint. Bands 9 and 6 are very strong, 5 strong, not certainly double, 4 faint, 3 stronger. Between 5 and 6 a line. The spectrum in general resembles that of 152 *Schj.* On one occasion several bands were suspected in the blue zone; this zone also appears to terminate in a bright line. (Ss I 95.5.4. Ss III 95.5.4, 97.4.26. Ss IV 97.4.26.)

BD. + 38° 2389 (8.0^m).

Rg = 7.5. Sp. III *b!!* 3 zones and perhaps a faint trace of the ultra-violet one. The yellow subzone bright; bands 9 and 6, especially the latter, very strong. (Ss I, Ss III 97.4.26.)

182 SCHJ. = 439 BIRM. = V CORONAE (VAR.).

Rgj = 8.5. Sp. III *b.* 3 zones, the blue one faint. Band 9 strong, band 6 very dim; no other details. (Ss I, Ss III 95.4.30, 95.5.2, 97.4.26.)

545 BIRM. = BD. + 36° 3168 = T LYRAE (VAR.).

Rrrg = 9.1. Sp. III *b!!* 2 bright and a hardly visible blue zone. The yellow subzone very bright. Band 6 very strong, 5 and 4 rather strong, 3 quite faint. 2 was also suspected on one occasion. (Ss I, Ss III 95.8.16, 95.8.18, 95.8.25, 96.8.14, 96.9.1.)

561 BIRM. = BD. + 36°3243 (7.5^m).

Rrg = 8.2. Sp. III *b!!* 3 zones, the blue one bright. The yellow subzone is not especially bright. Band 9 is very broad

and strong, 6 broad and strong, 5 rather strong, 4, 3 well seen, 2 very faint. (Ss I, Ss III 95.8.16, 95.8.18, 95.8.25, 96.8.13, 97.8.24).

229 SCHJ. = 607 BIRM. = BD. + 76°734 (6.5^m).

Rrg = 8.5. Sp. III *b!!!!* 4 zones, the ultra-blue one not especially faint. Bands 9, 10 very broad and dark. 4 is rather broad and very dark, after 9 and 10 the strongest detail in the spectrum, 5 broad, grayish, perhaps double, 6 rather broad but dim, 2, 3, and 8 well seen, 7 rather faint. (Ss I 93.8.6, 93.10.29, 95.9.3, 95.9.25. Ss II 93.10.29. Ss III 95.9.3, 95.9.25, 95.9.26, 96.8.13. Ss IV 96.8.13.)

608 BIRM. = BD. + 45°2906 (8.6^m).

Rrg = 8.6. Sp. III *b!!* 3 zones, the blue one very faint. The yellow subzone rather bright. Bands 9 and 6 very strong, 5 well seen, 4 faint. (Ss I 93.8.6, 95.9.9, 95.9.22. Ss III 95.9.9, 95.9.22.)

616 BIRM. = BD. + 32°3522 (8.0^m).

Rrg = 8.3. Sp. III *b!!!* 4 zones, the blue one bright, the ultra-blue one very faint. Bands 9, 10, 6 are exceedingly broad and strong, 5 strong, 3, 4 well seen, 4 stronger than 3. Bands 8 and 2 hardly seen with certainty. (Ss I 93.8.7, 95.8.15, 95.8.16, 95.9.22, 95.9.23. Ss III 95.8.15, 95.8.16, 95.9.22, 95.9.23.)

BD. + 85°332 (9.2^m).

Rg (peculiar color) = 6.8 Sp. III *b!!* 3 zones, the green one brightest, the blue not faint. Band 9 strong and broad, 6 rather faint. Band 4 suspected on one occasion. (Ss I, Ss III 96.8.14, 96.8.31, 96.9.9.)

627*a* BIRM. (9.5^m).

Rrg = 8.0. Sp. III *b!* 3 zones. Bands 6 and 9 rather strong. (Ss I, Ss III 95.8.16, 96.8.31, 96.9.29.)

639*a* BIRM. = BD. + 20°4394 (9.4^m).

Rrg = 8.0. Sp. III *b!!* 3 zones, all of them bright. The

yellow subzone not very bright. Bands 9 and 6, particularly 9, are very broad and dark. Star brighter than the 9th magnitude. (Ss I, Ss III 96.9.9, 96.10.2.)

643 BIRM. = BD. + 20°4417 (8.9^m).

Rrg = 8.0. Sp. III *b!!* 3 zones, the blue one rather faint. Bands 9 and 6 are very strong, 8 perhaps visible; otherwise no details. (Ss I, Ss III 97.8.30.)

650 BIRM. = BD. + 47°3031 (8.0^m).

Rrg = 8.4. Sp. III *b!* 3 zones, the green one very bright, the blue one somewhat faint. The yellow subzone rather bright. Bands 9 and 6 are strong. (Ss I, Ss III 95.8.6, 95.8.18, 95.8.25, 96.9.1.)

651 BIRM. = BD. + 35°4002 (9.5^m).

Rrg = 8.3. Sp. III *b!!* 3 zones, the green one very bright, and also the blue one bright. Bands 9 and 6 exceedingly broad and dark. (Ss I 93.10.3, 93.10.29, 95.8.16, 96.8.12, 96.8.13. Ss III 95.8.16, 96.8.12, 96.8.13.)

657 BIRM. = BD. + 38°3957 = R S CYGNI (VAR.).

Rrg = 8.5. Sp. III *b!* 3 zones; the yellow and red subzones rather bright. Bands 9 and 4 very well developed; 5 and more especially 6 are faint, 2 and 3 exceedingly faint. (Ss I 93.9.21, 93.10.13, 93.10.22, 95.8.25, 95.8.28. Ss III 95.8.25, 95.8.28.)

659*a* BIRM.

Rrg = 8.2. Sp. III *b!* 3 zones, the blue one very faint. Band 9 extraordinarily broad and strong, 6 broad and strong. (Ss I, Ss III 95.8.28, 95.9.9.)

662*a* BIRM. = BD. + 37°3876 (9.5^m).

Rrg = 8.6. Sp. III *b!* 3 zones, the green one the brightest. Bands 9 and 6 are broad and quite dark. (Ss I 93.8.7, 95.9.17, 95.9.23, 96.10.6. Ss III 95.8.18, 95.9.17, 95.9.23, 96.10.6.)

665 BIRM. = BD. + 37°3903 (9.4^m).

Rrg = 8.7. Sp. III *b*. 2 or possibly 3 zones. The bands are broad but dim. (Ss I 93.8.7, 95.9.27. Ss III 95.9.27, 96.11.1.)

681 BIRM. = V CYGNI (VAR.).

Rrrg = 9.5. Sp. III *b!!* 2 bright zones; band 6 broad. (SsI, Ss III, 97.9.3.)

BD. + 32°3954 (9.4^m).

Rrg = 8.8. Sp. III *b!!* 3 zones, the green one the brightest, the blue one somewhat faint. Bands 9 and 6 are strong and broad. (Ss I, Ss III 95.10.15, 96.9.15, 96.10.6.)

248 *b* SCHJ. = 705 BIRM (9.5^m).

Rrg = 8.3. Sp. III *b!* 3 zones, the green one the brightest, the blue one rather faint. Bands 9 and 6 are strong and broad. (Ss I 93.8.23, 93.10.30, 95.8.16. Ss III 95.8.16.)

250 SCHJ. = 710 BIRM. = S CEPHEI (VAR.).

Rrrg = 9.4. Sp. III *b!!* 2 bright zones and a hardly visible blue one. The yellow subzone is not especially bright, but bands 4 and 5 are visible. Band 6 is rather strong. (Ss I, Ss III 95.12.9, 97.4.26, 97.9.3.)

249 *a* SCHJ. = 711 BIRM. = BD. + 34°4500 (6.2^m).

Rrg = 8.4. Sp. III *b!!!!* 4 zones; three of them very bright, the ultra-blue one somewhat faint. The yellow subzone is brilliant. Bands 9 and 10 are very broad and strong, 6 considerably fainter; near its head, toward the yellow subzone, a narrow, faint, *bright* line. Band 5 is clearly double; the more refrangible component is stronger than the other. 4 is not so broad as 5, but at least as strong. Between 5 and 6 a very narrow and faint line. 8 and 7 are clearly visible, 2 somewhat stronger than 3; both rather faint, 1 faint. (Ss I 93.8.6, 93.8.23, 93.10.23, 93.10.30, 93.11.5, 93.11.23. Ss II 93.11.5, 93.11.23. Ss III 93.11.23, 93.11.26, 93.11.28, 95.9.1. Ss IV 96.8.2, 96.8.12, 96.8.14, 96.9.6, 96.9.9, 96.9.20, 97.8.24.)

251 SCHJ. = 713 BIRM. = R V CYGNI (VAR.).

Rrrg = 9.2. Sp. III *b!!* 3 zones, the blue one very faint. The yellow subzone rather bright. Band 6 is broad and strong, 5 well seen, 4 fainter than 5, 2 and 3 exceedingly faint. (Ss I 93.8.6, 93.8.23, 93.10.23, 93.11.7. Ss III, 95.9.9, 96.9.6. Ss IV 96.8.14, 96.9.6.)

257 SCHJ. = 720 BIRM. = BD. + 49°3673 (9.1^m).

Rrrg = 8.9. Sp. III *b!!* 2 bright zones and a hardly visible blue one. The yellow subzone bright. Band 6 is extraordinarily broad and dark. Bands 4 and 5 not certainly visible. (Ss I 93.8.6, 95.11.19, 96.9.1, 97.9.3. Ss III 95.9.19, 96.9.1, 97.9.3.)

19 PISC. = 273 SCHJ. = 756 BIRM. = BD. + 2°4709 (6.2^m).

Rrg = 8.5. Sp. III *b!!!!* 4 zones, the ultra-blue one not especially faint. The yellow subzone is very bright. Bands 9 and 10 are very broad and dark. 6 consists, beginning at the yellow, of (1) a rather strong and broad dark line; (2) a *bright* line; (3) a very faint shading. This whole band is remarkably faint. 4 is sharp, broad and dark, 5 very distinctly double, composed of two not strong lines. 3 is narrow but rather dark, even darker than one of the components of 5. 2 is dim but broad, 1 faint, 8 well seen, 7 faint. Between 5 and 6 a narrow faint line was seen on one occasion. (Ss I 93.10.15, 93.10.30, 93.10.31, 93.11.23. Ss III 93.11.23. Ss IV 96.8.13, 96.9.6, 96.9.9, 96.9.18, 96.9.20, 96.12.3.)

280 SCHJ. = 764 BIRM. = BD. + 59°2810 (7.8^m).

Rrg = 8.4. Sp. III *b!!!! Unique,* not because of the strength of the chief bands, for these are faint. Band 9 is fairly conspicuous, but not very broad, 10 much fainter, and 6 fainter than all the other bands. On account of the slight strength of the chief bands, the intensity of the spectrum gradually falls off towards the blue, so that the ultra-blue finally becomes exceedingly faint. Band 4 is as broad as half the yellow sub-

zone, quite black, and the most conspicuous detail in the whole spectrum. 2 is as strong as 9, or even stronger, broad and sharply terminated ; 5 is easily visible, 3 narrow and faint. (Ss I 93.9.23, 93.10.11, 93.10.15, 93.10.23, 93.10.29, 93.10.30, 93.10.31, 93.12.2. Ss III 93.11.23, 93.12.2, 95.9.9, 95.9.17, 95.12.9, 96.9.9. Ss IV 96.8.12, 96.9.6, 96.9.9.)

765 BIRM. = BD. $+42°4824$ (9.4^m).

Rrg = 8.0. Sp. III *b !!* 4 zones, the ultra-blue one exceedingly faint. Band 9 is very strong and broad, 6 only a little fainter. The yellow subzone is rather bright; bands 4 and 5, particularly the latter, visible but faint. (Ss I 93.10.5, 93.10.30, 93.10.31. Ss III 95.9.9.)

It appears in the first place from these observations that in spectra of all bright stars of class III *b*, namely W Orionis (6.0^m), 78 *Schj.* (6.3^m), 115 *Schj.* (6.5^m), 318 *Birm.* (6.2^m), 152 *Schj.* (5.5^m), 229 *Schj.* (6.5^m), 249 *a Schj.* (6.2^m), and 19 Piscium (6.2^m) band 5 is double, and in band 6 near the less refrangible edge there is a bright line, while these details cannot be made out with certainty in the spectra of the only slightly fainter stars 7 *Schj.* (7.0^m), 41 *Schj.* (7.0^m), 74 *Schj.* (6.5^m), and 155 *b Schj.* (7.3^m). In some of the latter spectra band 5 is nevertheless very broad. It must consequently be regarded as highly probable that both of these details are common to all spectra of type III *b*. They are, moreover, clearly visible in Professor Hale's photograph of the spectrum 152 *Schj.*

In a closer comparison of the spectra of different stars one is struck by the very marked differences of the relative strength of certain bands. This is particularly the case with bands 6 and 4. For example, in the spectrum of 152 *Schj.* band 6 is almost as strong as band 9, and is consequently one of the most striking details of the spectrum, while band 4 is quite faint. On the other hand, in the very remarkable spectrum of 280 *Schj.*, 4 is the strongest and 6 the faintest visible band in the whole spectrum, in fact fainter than bands 2–5 and 9 and 10. Of the

remaining stars of this class, some, considered with reference to the relative intensities of bands 4 and 6, resemble 152 *Schj.*, while others are more like 280 *Schj.;* but so far as my experience goes the great strength in the spectrum of this star of band 4, combined with the remarkable faintness of band 6, is met with in the same degree in no other spectrum.

Of the spectra belonging to type III *b*, those of RS Cygni, 19 Piscium, 7 *Schj.*, 74 *Schj.*, 235 *Birm.*, 229 *Schj.*, *BD.*+ 85°332, and 249*a* *Schj.*, although, as has been said, having band 6 relatively stronger, resemble that of 280 *Schj.;* the spectra of 64 *Birm.*, 41 *Schj.*, 155*b* *Schj.*, 608 *Birm.*, 616 *Birm.* correspond more closely with that of 152 *Schj.;* and those of other stars, for example W Orionis, 78 *Schj.*, 115 *Schj.*, 72 *Schj.*, 64*a* *Schj.*, 643 *Birm.*, 634 *Birm.*, 318 *Birm.*, etc., occupy an intermediate position.

To base upon these differences in the relative intensities of these bands a division of class III *b* into subclasses, would, in my opinion, hardly be advisable. The various classes, particularly if one does not represent an evolutionary step beyond that which immediately precedes it, must show *fundamental* differences, and the relative intensities of the lines are not to be regarded as such. Moreover, one might easily get as many subdivisions as there are stars. On the other hand, as Professor Hale remarks, it should be possible to arrange these stars in a series. I shall make no investigations in this direction, since Professor Hale is engaged on this very problem, and neither the refractor nor the atmospheric conditions at Upsala can be compared with those at the Yerkes Observatory.

UPSALA,
January 23, 1899.

ON SOME PHOTOGRAPHS OF THE GREAT NEBULA IN ORION, TAKEN BY MEANS OF THE LESS REFRANGIBLE RAYS OF ITS SPECTRUM.

By JAMES E. KEELER.

IN a short article[1] published some years ago, I suggested that certain differences between the forms of nebulae as shown by drawings and by photographs may be due to the non-homogeneous structure of these nebulae. It was not asserted that the cause here mentioned is sufficient to account for all the differences which are actually found, for drawings differ among themselves quite as much as they do from photographs, but it is a cause which must have some effect in producing the differences referred to, and which must be taken into account if we admit the possibility that the spectrum of a nebula may not be the same in all its parts.

That this non-homogeneous structure exists in some cases may now, I think, be regarded as proved. A striking example, though one on a small scale, is afforded by the small planetary nebula *SD.*— 12°1172. When this nebula is examined by means of a spectroscope attached to a large telescope, the slit being opened so as to include the entire image of the nebula, three circular, well defined, uniformly illuminated disks are seen, corresponding to the nebular lines λ 5007, λ 4959 and $H\beta$. These disks are of unequal diameters, that of $H\beta$ being largest and that of λ 4959 smallest. This remarkable peculiarity of the nebula was discovered by Professor Campbell[2] in 1893, and I have recently had an opportunity to verify his observations with the 36-inch refractor. I may also note, as a slight digression, that the difference in size between the images representing the chief and second nebular lines is the only evidence in our possession, so far as I am aware, that these lines are not due to the

[1] *Pub. A. S. P.*, 7, 279, 1895.

[2] *Pub. A. S. P.*, 5, 207.

same substance. The evidence is not conclusive, but its weight is in the direction above pointed out.

In the case of the Orion nebula, non-homogeneity was suspected by Huggins as long ago as 1868, and again by Henry Draper,[1] on the strength of a photograph of the spectrum taken in 1882. Draper tried to obtain photographic impressions of the monochromatic images formed by a telescope and direct-vision prism, but further investigations in this direction were brought to an end by his untimely death.

Very considerable differences in the spectrum were found, and their amounts estimated, by Campbell[2] in 1893. While the chief nebular line λ 5007 was the strongest line in the spectrum of the Huyghenian region, the $H\beta$ line was strongest in the spectrum of remote regions and fainter streams of nebulosity.

The conclusiveness of Campbell's observations has been questioned, on the ground that the observed phenomena may be explained as the result of physiological causes. It has been shown, however, that the physiological effect in question is entirely inadequate to account for the great differences of brightness actually observed, while the observer was in fact on his guard against just such influences.

Some observations of my own, made with special reference to this question, seem to be absolutely conclusive. The nebula was examined on the night of December 12, 1898, with a spectroscope attached to the 36-inch refractor. The appearances described by Campbell were easily recognized. By reducing the aperture of the spectroscope the brightness of the spectrum was diminished without changing in any way the quality of the light. It was found that with a sufficiently feeble spectrum the $H\beta$ line was alone visible in one part of the nebula (the nebulosity surrounding the star Bond 734) and the chief line was alone visible in another part (the Huyghenian region)—a result which is inexplicable on physiological grounds, and can only be due to real differences in the spectrum of the nebula.[3]

[1] *Am. Jour. Sci.*, **23**, 340.

[2] *A. N.*, 3205. *A. and A.*, **13**, 384.

[3] *A. N.*, 3541.

One or two other observations bearing on this question may also be appropriately mentioned here. In 1888 the spectrum of the Huyghenian region was photographed by Professor Wm. H. Pickering[1] with an 11-inch object-glass spectroscope, each line of the spectrum being therefore represented by a monochromatic image of the nebula. It was found that the radiations corresponding to the ultra-violet line λ 3727 are particularly strong in the southeast border of the Huyghenian region, and also in the part just west of the trapezium. The spectrum is reproduced in Fig. 5, Plate II, *Annals H. C. O.*, Vol. 32.

A dull red fringe along the southern boundary of the Huyghenian region has been described by Professor Barnard.[2] If this appearance is not subjective, it would indicate the existence of a line or lines (presumably $H\alpha$) in the lower spectrum, which one might expect to be visible in the spectroscope. Attempts made at Mt. Hamilton to see a red line in the spectrum of this region have been unsuccessful.

Quite recently I observed the Orion nebula, on a fine clear night, with the 36-inch equatorial. The red fringe was distinctly seen in the place indicated by Barnard, and, less clearly, at other places on the border of the Huyghenian region. A thin slip of light red glass, through which the nebula was dimly visible, caused the disappearance of the fringe, and no red line could be seen with a small direct-vision spectroscope. On the whole, I am disposed to regard this red fringe as a subjective phenomenon, though I do not consider the evidence in favor of this view as entirely conclusive.

It would appear at first sight that the best method of studying the distribution of the different nebular radiations is that attempted by Draper and successfully applied by Pickering. Practically, however, this method does not yield entirely satisfactory results. The fainter parts of the nebula do not appear, and even the images of the Huyghenian region overlap and are therefore confused. The stars are drawn out into spectra, and are no longer available as reference points, while the strong con-

[1] *Annals H. C. O.*, 32, 74. [2] *Knowledge*, 17, 97, 1894.

tinuous spectra of the brighter stars practically obliterate the images formed by the less refrangible rays.

In the article which has been referred to I suggested the use of an orthochromatic plate, protected by a color screen, for accomplishing the same purpose. Having now at my disposal an instrument—the Crossley three-foot reflector—which is extremely effective for the photography of nebulae, I have been able to carry out the experiments which were suggested in my earlier paper, and in what follows I give a description of the results.

The color screens were supplied by Mr. Carbutt, the well-known dry-plate maker, who kindly selected for me screens having a greener color than those generally used in orthochromatic photography. These screens were mounted in light frames, which fitted the double-slide guiding apparatus of the reflector, just in front of the photographic plate, and which could be easily removed when desired.

In order to understand precisely what is effected by the color screen, it is necessary to consider the composition of the light of the nebula, the selective absorption of the screen, and the sensitiveness of the plate to rays of different wave-lengths.

The visual spectrum of the Huyghenian region consists mainly of three bright lines: the $H\beta$ line, the line $\lambda 4959$, which has about the same intensity as $H\beta$, and the "chief" line $\lambda 5007$, which is several times brighter than either. The $H\gamma$ line is visible, but it is faint, and several other lines, due to helium and unknown substances, are seen with great difficulty under the best conditions. They contribute practically nothing to the image of the nebula seen in ordinary observation with the telescope. This image is practically formed by rays corresponding to the three lines first mentioned.

If the spectrum of the same region is photographed on an ordinary dry plate, a large number of lines appears, the strongest of which are $H\gamma$ and the ultra-violet hydrogen series. There is also a very strong line at $\lambda 3727$ discovered by Huggins. The $H\beta$ line is fairly strong, the second line ($\lambda 4959$) considerably

weaker, and the chief line about as strong as $H\beta$. This change in the relative intensities of the last three lines, as compared with the visual intensities, is due to the falling off toward the yellow of the curve of sensitiveness of the photographic plate.

If the spectrum is photographed on an orthochromatic instead of an ordinary plate, the appearance is much the same as that just described. The principal difference is in the relative intensities of the three lowest lines, which now, on account of the rise of the curve of sensitiveness toward the yellow, approach more nearly the visual intensities. The $H\beta$ line is, however, relatively a little too strong.

One of the screens furnished by Mr. Carbutt is of a strongly yellowish-green color. It entirely suppresses the upper end of the spectrum, the absorption extending to a little below the $H\beta$ line, which is reduced in intensity about one half. The other screen, which is green with only a slightly yellow tinge, also completely suppresses the violet end of the spectrum, but the absorption does not extend so far toward the yellow. The $H\beta$ line is transmitted without perceptible loss. Both screens of course strongly absorb the red, where their effect is immaterial in connection with the present investigation. They were tested visually with the solar spectrum, and photographically with the hydrogen spectrum, on both ordinary and orthochromatic plates.

It will be seen that the effect of these screens, when used with the reflector in the way I have described, is to cut off all the rays from the nebula except those which form the visual image. If the image thus modified is photographed on an orthochromatic plate, it will represent very closely the image seen by the eye in ordinary observation, the relative visual intensities of the three principal species of rays being approximately preserved. This condition is more closely fulfilled by the first than by the second screen, though at the expense of a general diminution of brightness. As the loss of light proved to be important, the second or green screen was generally used.

It is to be observed that the relative importance of the upper spectral lines in producing an ordinary photograph is much

greater with an instrument like the Crossley reflector than with a refractor, and greater than one might infer from a consideration of the spectrum as photographed with glass prisms. How powerfully the ultra-violet rays of the nebula are absorbed by a great thickness of glass is shown by some comparisons that I have made of photographs taken with the Crossley telescope and earlier photographs taken with the 33-inch photographic objective of the 36-inch refractor. With the reflector more nebulosity is shown in five minutes than appears on photographs taken with the refractor with exposures of from two to three hours. A part of this enormous difference is however due to the greater angular aperture of the reflector.

By the method which is described above, it is possible to obtain photographs which are directly comparable with the image seen in the telescope, and therefore with drawings. But the comparison of such photographs with drawings, or with photographs taken by the ordinary methods, must be made with due regard to certain peculiarities of photographic action, or the results may be misinterpreted. Without a series of elaborate subsidiary investigations, little can be predicated from the mere fact that two unequally dense parts of a photographic image have a certain ratio of intensity. Given two unequally bright objects, their photographic images may be made to have almost any desired relative intensity. This ratio is affected by the length of the exposure, the manner of development, the kind of plate used, and other variable factors. Indeed, it is quite possible to reverse the order of intensity, so that the brighter object may give the weaker image. These photographic phenomena are constantly taken advantage of in ordinary photographic operations. About all that it is safe to assume is, that (setting aside certain limiting conditions not likely to be met with in nebular photography), equally dense parts of the negative correspond to equally bright parts of the object. Here it is also taken for granted that the *quality* of the light is the same in both cases.

In these experiments I wished to be able to draw conclusions from differences as well as from equality of density. What I

aimed at, therefore, was to produce two photographs of the nebula on the same night, one taken on an ordinary plate and in the ordinary manner, the other taken with the color screen and on an isochromatic plate, the exposures in the two cases being so timed that, when the plates were placed in a tray and developed together, the Huyghenian region should develop in the same manner on both negatives, and should appear equally dense when they were fixed. These conditions were in fact pretty closely fulfilled in practice.

For example, on February 9, 1899, an orthochromatic plate, protected by the color screen, was exposed in the telescope for two hours and twenty minutes. The screen was then removed, and exposures of four, five, and six minutes respectively were given to three ordinary plates. The four plates were placed in a tray and developed together, and it was found that the four-minute plate and the orthochromatic plate developed with about equal rapidity.

In these experiments the focus was adjusted by means of an achromatic eyepiece. When the screen was used, the focus was adjusted with the screen in place, and when the screen was removed the focus was readjusted, the change of focus caused by the thickness of the glass being quite perceptible in the case of an instrument having so large an angular aperture as the Crossley reflector.

The plates used with the screen were the Cramer "Isochromatic Instantaneous." The best photograph was, however, taken with one of the ordinary plates (Cramer's "Crown"), stained with a dilute ammoniacal solution of erythrosin, and used on the evening of the day on which it was prepared.

I have now to describe the results of the investigation. In one respect these have been disappointing. I had hoped that with the color screen and orthochromatic plate an exposure of two or three hours would be sufficient to give a good picture of the nebula, including even the faintest portions — such a picture as the eye would see if its sensitiveness could be greatly increased. But the actinic power of the less refrangible rays of the nebula

proved to be so feeble that an exposure of many hours would have been required for this purpose.

Comparing the photographs made by the two methods which have been described, we have, as the principal result of the investigation, the fact that when the intensity of the Huyghenian region is the same in each case, the intensity of the remote parts of the nebula and outlying streamers is very much less on the photographs taken with the color screen on orthochromatic plates. Conversely, where photographs made by the two methods, on the same night, show an equal extent of nebulosity, the Huyghenian region is very much more intense on the orthochromatic plate. We infer, therefore, that in the remote parts of the nebula the two lowest nebular lines are weak, or the hydrogen lines strong, as compared with the Huyghenian region. Thus the results of spectroscopic researches are confirmed, and are extended to parts of the nebula which are too faint for visual observation.

A check on the results, which I have not yet referred to, is afforded by the numerous stars scattered through the nebula. The brighter stars in the nebula, and the Orion stars generally, are of the first type, and very rich in violet light. It may pretty safely be assumed, therefore, that the great majority of the small stars in the nebula are also of the first type, and hence that their photographic activity is reduced by the color screen in at least as great a ratio as that of the nebula. Now on orthochromatic plates obtained as above, both stars and Huyghenian region are strong, while on the ordinary plate, with weaker stars and Huyghenian region, a far greater amount of diffuse nebulosity is shown.

By far the most obvious effect of the color screen is to reduce the intensity of all the fainter parts of the nebula, as compared with that of the Huyghenian region. Not all the fainter regions are however depressed in the same proportion, and some of these cases call for special remark.

The long scimiter-like streamer extending from the central part of the nebula toward the south — the *Proboscis Major* — seems to be the least affected of all the outlying parts. It is

quite strong on the photographs taken with the color screen. Now this streamer is easily visible with telescopes of moderate size, having been discovered, in fact, by Messier, as far back as 1771, with a telescope of 3.3 inches aperture. We may infer that the first and second nebular lines are fairly strong in its spectrum.

Close to the streamer, on the west, and running parallel to it, is a shorter streamer, which is not easily visible. It is not shown in the drawings of Herschel, Lord Rosse, Bond, or Trouvelot, or in any of the drawings I have examined, except Lassell's drawing of 1862[1], where it is quite accurately represented. I see it without much difficulty with the Crossley reflector, though of course with the advantage of a knowledge of its existence.

The photograph taken with the color screen accords perfectly with the view in the telescope. The Messierian branch, or *Proboscis Major*, is strong and well defined; the parallel branch is but faintly visible. But on an ordinary photograph these two branches are of very nearly equal intensity, so that it is hardly possible to photograph the first without showing the second. This I regard as one of the most interesting results of the investigation, as it explains at once the cause of a striking discrepancy between celebrated drawings and photographs taken by the methods hitherto in use. The principal (lower) nebular lines are relatively strong in the spectrum of the Messierian branch, and the hydrogen lines are relatively strong in the spectrum of the companion streamer.

The nebulosity surrounding the star Bond 734, north of the main nebula, is greatly weakened by the color screen. The spectroscopic observations of this region which have been made here by various members of the Lick Observatory staff, by Professor Runge, and by myself, showing the great predominance of the hydrogen lines, are thus confirmed. The image photographed through the color screen is no doubt almost entirely due to the $H\beta$ line.

West of the brighter part of the nebula is a series of beauti-

[1] *Knowledge*, **12**, 149, 1889.

ful curves of nebulosity, which begins about midway between the stars Bond 335 and 387 and extends toward the northeast. The scalloped edges of this nebulous stream have very considerable actinic power. They are easily photographed with an exposure of two minutes on an ordinary plate, on which they have about the same intensity as the Messerian branch.

These bright edges are not shown on any of the drawings that I have examined, and I have not been able to see them with the Crossley reflector. Their invisibility is explained by these experiments in the same way as in the other cases I have mentioned. The edges of the loops are shown, very faintly, on only the strongest of the photographs taken through the color screen, and hence their actinic power may be attributed to the upper series of hydrogen lines in their spectrum.

It was my intention to illustrate this article with photographs of the nebula taken by the two different methods, so that the reader would be enabled to make his own comparisons; but the great differences of density incident to the insufficient exposures make the negatives unsuitable for reproduction, and I have therefore contented myself with a description of the results.

Mr. H. K. Palmer and Mr. E. F. Coddington, holding Fellowships at the Lick Observatory, have rendered efficient assistance in the observations.

Lick Observatory,
Mt. Hamilton, March 1, 1899.

ON THE WIDE COSMICAL DISSEMINATION OF VANADIUM.

By B. HASSELBERG.

IN a previous communication to this JOURNAL[1] I have pointed out the interesting fact that the mineral rutile generally contains vanadium in small amount, but varying from one specimen to another. This result was first arrived at by comparing the arc-spectrum of titanium with that of vanadium, the former having been produced by introducing a small fragment of a Norwegian rutile into the arc, whereby some of the most important vanadium lines appeared therein as impurities. Among the lines thus observed the brilliant group at $\lambda 4408-4379$ is the first to appear, the presence of even the slightest trace of the metal in the arc being sufficient for this purpose. On account of this fact I have generally employed this group of lines for the spectroscopic investigation of the different rutiles in this respect, and with the result stated above. Now the circumstance that among the results of ordinary chemical analysis of the mineral in question quoted by Dana[2] nothing about the presence of vanadium occurs, made the supposition that the observed fact would be an entirely new one very probable, the more so as the smallness of the amount of the metal entering into the composition of the rutiles seemed sufficient to explain the failure to detect it by ordinary chemical methods. This is, however, not the case, because as I have lately found, vanadium was discovered in rutile from St. Yrieix in 1861 by the analyses of St. Claire-Deville.[3]

In addition to the rutile from St. Yrieix vanadium was met with, according to St. Claire-Deville, in many other minerals, the number of which has lately been considerably increased by the researches of Dieulafait, Becchi, and especially Hillebrand, who

[1] This JOURNAL, **6**, 1897.

[2] DANA, *Descriptive Mineralogy*, 5th edition, New York, 1883, p. 160.

[3] *Annales de Chimie et de Physique*, III Série, **61**, 342, 1861.

by careful analysis has determined the small quantities of vanadic oxides contained in a great multitude of the most heterogenous substances.[1] Thus vanadium, although in general quantitatively very scarce, must be considered as one of the most widely disseminated chemical elements on the Earth.

As to the occurrence of vanadium in the heavenly bodies, there can be no doubt that this metal enters into the composition of the general reversing layer of the Sun. Indeed, the detailed investigation of its spectrum in the electric arc, which I have just finished,[2] shows that from the several hundreds of lines determined therein a considerable number correspond to absorption lines in the general solar spectrum. But it is a remarkable fact that the lines thus represented are only the very strongest and that the solar lines matching them are generally exceedingly faint, while the lines of medium and feeble intensity in the spectrum of the metal are totally wanting in the Sun. This seems to indicate that the quantity of vanadium vapor present in the general absorbing layer is rather insignificant, or that it is mainly restricted to regions of more elevated temperature. The contrast in this respect is very striking between the general surface of the Sun and the spots, in the spectra of which the vanadium lines, according to Young, play a very prominent part.

How far it may be possible to trace vanadium in the atmospheres of the stars is a question impossible to settle at present. On account of the extraordinary weakness of its absorption lines in the general solar spectrum, it is evident that for this purpose we must learn much more than we know at present regarding the details of stellar spectra. However, the many analogies existing between the Sun and the stars make the supposition of the presence of the metal among their constituent elements at least not improbable, especially in cases where there are reasons to suspect the existence of numerous spots.

Besides the great suns peopling space there is another class of cosmical bodies, the chemical investigation of which is of no

[1] *American Journal of Science*, **6**, 1898.

[2] This investigation will soon be published.

less importance, namely, the meteorites. This is particularly true, as in their case the chemical analysis can be made with a far greater degree of completeness than is possible to attain for all other heavenly bodies with the methods of research now available. It seems rather strange that spectrum analysis, the different applications of which are so numerous and profitable, has been so little employed in this field. Indeed, so far as I am aware, the researches of Lockyer upon the arc-spectra of the Nejed and Obernkirchen meteoric irons,[1] and those of Hartley and Ramage concerning the spectra of certain meteorites in the oxyhydrogen flame,[2] are the only instances of any importance in this direction. Now it is scarcely necessary to point out the fact that, in order to acquire a more accurate knowledge of the cosmical distribution of the chemical elements, an extensive use of spectroscopic methods is most likely to supply the necessary data. From this point of view I have lately undertaken to investigate by means of spectrum photography the arc-spectra of a considerable number of meteorites of different countries and dates. I owe the possibility of these researches to the kindness of Baron Nordenskiöld, who for this purpose has placed the great collections of the Royal Museum at my disposal.

Among the results already obtained from a first review of the spectrum photographs I will confine myself for the present to those regarding the presence of vanadium in these bodies. For the settlement of this question I have photographed on the same plate the aforesaid principal group of the vanadium spectrum and adjacent lines, together with the same part of the spectrum of the meteorite under investigation. From a careful scrutiny of the plates thus obtained it is easily decided whether or not the metal is present in the meteorite. The results of this investigation are contained in the following table, in which the first column gives the names of the meteorites, together with the designation of their general character as stones (S) or irons (I), and the succeeding columns the comparative inten-

[1] *Phil. Trans.*, **185** A, 1023, 1894.

[2] *Scientific Proceedings of the Dublin Society*, **8**, 1898.

sities in their spectra of the vanadium lines, the wave-lengths and proper intensities of which are indicated at the top of every column. The scale of intensity is such that the numbers 6 . . . 1 designate its successive steps from the strongest to the weakest lines; lines of intermediate intensity are indicated by two numbers, as 1.2, 2.3, or by the signs + or — annexed to the numbers:[1]

From an inspection of this table it is immediately evident that the amount of vanadium contained in the meteorites is certainly very small. Indeed, the intensity of its lines in their spectra is generally very insignificant compared with the almost dazzling brilliancy of the same lines in the spectrum of the metal. But, on the other hand, the behavior of the different meteorites in this respect is very dissimilar, and consequently also the relative amount of vanadium entering into their composition must vary in a corresponding degree. Thus the meteorites from New Concord, Lundsgården, Knyahinya, and Soko-Banja, for instance, are certainly much richer in vanadium than those from Ställdalen, Hessle, Cléguérec and several other places. Another fact of very high importance, I think, immediately strikes the eye, namely, that all meteoric *stones* invariably contain more or less vanadium, while in the meteoric irons proper not the least trace of the metal has been found.[2] In conformity with this the mesosiderites, which, from a mineralogical point of view, take an intermediate position between the stones and irons, in some cases contain a small amount of vanadium, in others are completely destitute of it. From this remarkable behavior of the two main classes of meteorites, it may be inferred with a not inconsiderable degree of probability that their cosmical origin is also different.

In his spectroscopic researches upon the Nejed and Obernkirchen meteoric irons Lockyer has also mentioned vanadium among the elements which are with some probability present

[1] The symbol *tr* indicates that the line in question is present only as a barely visible trace.

[2] The only exception to this general rule is the meteoric iron from Greenland. May not this perhaps be a terrestrial ore?

Name and character of the meteorites	Wave-length and intensity of Vanadium lines																										
	4444.40	41.88	38.02	36.31	29.95	28.63	26.17	21.73	16.63	08.67	08.35	07.85	06.80	00.74	4395.40	90.13	84.87	79.38	53.02	41.15	32.98	30.18	09.95	4291.96	84.19	77.13	71.70	68.78
	3·4	3·4	3·4	3·4	3	3	3	3	3	4·5	4	4·5	4·5	4	4·5	4·5	4·5	5	3·4	3	3	3	3	3	3	3	3	3
Ställdalen ....S	...	tr	tr	tr	...	tr	tr	...	tr	1	1	tr	1	tr	1+	1.2	2	2+	tr	1—	...	...	1	...	tr	...	...	...
Greenland I	1	1	1	1	tr	1	tr	tr	1	1+	1+	tr	1+	1+	2—	2	2.3	3	1	1	1—	1—	...	...	tr	tr	...	tr
Hessle ....S	...	...	...	...	...	...	...	...	...	tr	1—	tr	tr	...	1	1+	1.2	2—	...	tr	...	...	...	...	tr	...	...	...
Pallas .... I, S	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
New Concord ......S	1	1+	1	1	1—	1+	1	1	1+	1.2	2—	2—	2—	1.2	2	2+	2.3	3	1	1+	1	1	1+	1—	1	?	...	1—
Orgueil ... .S	tr	tr	...	...	...	tr	tr	...	tr	1	1	1—	1—	tr	1+	1.2	2—	2	tr	1—	...	...	tr	tr	tr	...	...	...
Atacama, Chili .... I, S	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Ausson..............S	...	...	...	...	...	...	...	...	...	1—	1—	tr	tr	...	1	1.2	2—	2—	...	tr	...	tr	...	tr	...	...	...	...
Arva, Hungary I	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Cléguérec ....S	...	...	...	...	...	tr	tr	...	...	tr	1	...	tr	tr	1	1+	2—	2—	...	tr	...	...	...	...	...	...	...	...
Téheran .... I, S	...	...	...	...	...	...	...	...	...	1	1	tr	1	tr	1+	1.2	2	2+	1—	...	tr	...	...	...	...	...	...	...
Pultusk ....S	tr	1—	tr	tr	...	tr	1—	tr	1—	1+	1+	1+	1	1	1.2	2	2+	2.3	1—	1—	1—	tr	tr	1—	1—	tr	...	...
Red River I	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Toluca I	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Werschne Tschirskaja Stanetza ....S	1—	1—	1—	1—	...	1—	tr	1—	1—	1	1	1—	1	tr	1.2	2—	2	2+	1	1	1—	tr	1	tr	tr	...	...	...
MacKinney ....S	1—	1—	1—	tr	...	...	1—	1—	1—	1	1+	1	1—	1	1.2	2	2+	2.3	1	tr	1—	tr	tr	tr	1	tr	...	...
Loutolaks ....S	tr	1—	tr	tr	tr	1—	tr	1—	1—	1	1	1	1	1	1+	1.2	2	2+	1—	1	tr	tr	tr	tr	1	tr	...	tr
Lundsgärden ....S	1	1+	1	1	1—	1	1	1	1	1.2	1.2	1+	1+	1+	1.2	2	2+	2.3	1	1+	1	1	tr	tr	1—	tr	...	1—
Obernkirchen I	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Nejed I	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Bates County I	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Cañon Diablo........I	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Brenham, Kansas....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	tr	1—	1—	1—	...	...	...	...	...	...	...	...	...	...
Mezö-Madaras ......S	1—	1—	tr	...	...	...	tr	1—	1—	1	1+	1	1	1	1.2	2—	2	2+	1	1	1—	tr	...	tr	1	tr	...	...
L'Aigle ....S	1	1	1—	tr	...	1	1—	1—	1	1	1+	1	1+	1+	1.2	2	2+	2.3	1	1	1—	tr	...	...	...	...	...	...
Knyahinya..........S	1	1	1	1—	tr	1	1	1	1	1+	1.2	1+	1.2	1.2	2—	2	2+	2.3	1	1	1—	tr	...	...	1—	1—	...	tr
Alfianello ....S	1	1	1	1	tr	1	1	1	1	1.2	1.2	1+	1.2	1.2	2—	2	2+	2.3	1	1—	1—	tr	1	tr	1—	1—	...	1—
West Liberty ....S	1	1	1	1—	...	1—	1	1	1	1.2	1.2	1+	1.2	1.2	2—	2	2+	2.3	1	1	1—	1—	...	...	1	1—	...	1—
Soko-Banja ....S	1+	1+	1+	1	1—	1+	1	1	1+	1.2	2—	1.2	1.2	1.2	2—	2+	2.3	3	1+	1.2	1	1	...	...	1	1—	...	1—
Mocs ....S	1	1	1	tr	...	1	1—	1—	1+	1+	1	1+	1+	1+	2—	2	2+	2.3	1	1+	1—	tr	...	tr	1	tr	...	1—

therein. This conclusion is based on the occurrence in their spectra of the following four lines ascribed to this metal:

λ	λ
4119.6	4115.1
18.0	12.5

On comparing these positions with the spectrum of vanadium I find that only the first and the last are represented with sufficient accuracy by the lines 4119.58 and 4112.47, while in the two other cases the difference in wave-length from the nearest vanadium lines at λ 4118.34 and 4115.32 is too great to make the identity probable. But even supposing that the identity were perfect, this seems to be of little importance in view of the fact that among the lines in the meteoritic spectrum observed by Lockyer, the great principal vanadium group at λ 4408–4379 is completely wanting. From this circumstance it may with great probability be concluded that the lines named above do not really belong to vanadium, and that consequently this metal cannot be considered as entering into the composition of the two meteorites.

However, with the view of testing the matter more thoroughly, I have also photographed the vanadium group in question and its vicinity, together with the corresponding parts of the spectrum of the Nejed iron, but without finding on the photograph the least trace of the lines observed by Lockyer, with exception of 4118.34, which is prolonged as a very faint line in the Nejed spectrum. But this faint line belongs to carbon. If it further be added that of such adjacent strong vanadium lines as

λ	I	λ	I
4128.25	3.4	4109.94	3
23.65	3	05.32	3
16.65	3	02.32	3
15.32	3.4	4099.93	4
11.93	4		

and several others nothing is seen in the spectrum of the meteorite, it may safely be concluded, I think, that vanadium does not enter into its composition any more than in other specimens of the same class.

STOCKHOLM,
February 1899.

ON THE SPECTRUM OF THE GREAT NEBULA IN ANDROMEDA.

By J. Scheiner.

On account of their faintness the continuous spectra of the nebulæ have been hitherto little investigated. H. C. Vogel was able to recognize dark stripes in the spectrum of the readily resolvable cluster in Hercules, Messier 13, but it was impossible to measure them and thus to establish the nature of the spectrum. Vogel showed that it was a characteristic common to all continuous nebular spectra that the maximum of visual intensity is displaced from its usual position in the yellow toward the green. It is known today that this observation is to be attributed to physiological causes. Statements by other observers as to the continuous spectra of nebulæ are not known to me.

The continuous spectrum given by the Orion nebula in addition to its gaseous spectrum was easily photographed with a small spectrograph, which, in combination with a mirror of 32 cm aperture and 96 cm focal length, possessed an especially large light-power for objects of extended surface. This induced me to attempt to photograph the spectrum of the Andromeda nebula. With an exposure of three and one half hours the first traces appeared of a spectrum, in which a strong absorption band could be clearly perceived, which I took to be the $H\gamma$ line. This led me to carry the exposure still further, and thus I obtained, with the assistance of Dr. Ludensdorf, a plate of the spectrum of the Andromeda nebula with an exposure of seven and one half hours in January of this year. The continuous spectrum can be clearly recognized on it from F to H, and faint traces extend far into the ultra-violet. A comparison of this spectrum with a solar spectrum taken with the same apparatus disclosed a surprising agreement of the two, even in respect to the relative intensities of the separate spectral regions. The H line could be seen very distinctly, so that the band noticed on

the first plate could be referred to it. The measurement led to the indisputable result that the band corresponds to the G group in the solar spectrum and not to the $H\gamma$ line. It is thus proven that the Andromeda nebula exhibits a spectrum of Class II*a*, or further that the greater part of the stars composing the nucleus of this nebula belong to the second spectral class.

Since now our stellar system, viewed from a distance, would show a spectrum quite closely approximating that of the first spectral class, we may further reason that the system of the Andromeda nebula is now in an advanced stage of development. No traces of bright nebular lines are present, so that the interstellar space in the Andromeda nebula, just as in our stellar system, is not appreciably occupied by gaseous matter.

I beg to call attention on this occasion to a few further points. The Andromeda nebula belongs to the class of the spiral nebulæ which all give a continuous spectrum. Since the previous suspicion that the spiral nebulæ are star clusters is now raised to a certainty, the thought suggests itself of comparing these systems with our stellar system, with especial reference to its great similarity to the Andromeda nebula. The inner part of the Andromeda nebula corresponds to the complex of those stars which do not belong to the Milky Way, while the latter corresponds to the spirals of the Andromeda nebula. The irregularities of the Milky Way, especially its streams, can be quite well accounted for, as Easton has attempted to do, if they are regarded as a system of spirals and not as a ring system. The most important ground for this view to me lies in the fact that all the the ring nebulæ possess gaseous spectra, in contrast to the spiral nebulæ.

In spite of the unfavorable projection under which we see the Milky Way, it does not seem impossible to establish the spiral character of the principal forms, and, furthermore, to bring the proper motions of the stars of the Milky Way into relation with this.

POTSDAM, KGL. OBSERVATORIUM,
January 1899.

OBSERVATIONS OF THE LEONID METEORS OF 1898.

By E. E. BARNARD.

An early watch was begun here for the expected return of the Leonid meteors. Indeed, every clear night from the first of November was utilized for more or less prolonged watches. Cloudy and stormy weather, however, interfered very much.

One striking thing in these early watches was the remarkable scarcity of meteors of any kind.

A few of the notes in the first part of the month may be of interest as showing that the Leonids, probably, did not make any very early appearance.

Nov. 4. From $7^h\ 5^m$ to $10^h\ 40^m$ meteors were very scarce; only two or three faint ones were seen and none from the east.

Nov. 7. During the night casual inspections of the sky, during other observing work, showed no meteors.

Nov. 8. Cloudy all night.

Nov. 9. Cleared after dark. At $10^h\ 50^m$ a magnificent golden fireball, four or five times brighter than Venus, shot from near Alpha Cassiopeiae, and disappeared near the stars in the head of Draco (the 12-inch dome prevented its exact point of disappearance being ascertained). It passed about 4° north of Alpha Cephei. Very few meteors were seen during the entire night. At $17^h\ 0^m$ a Leonid appeared 30° south of the radiant, going southwards with a path of about 20° and leaving a faint trail. This was the only meteor that came at all from the direction of the radiant.

Nov. 11. Watched all night. No meteors seen in the first part of night. From $12^h\ 0^m$ to $12^h\ 40^m$ seven faint meteors were seen, one as bright as the fourth magnitude. These were moving towards Leo, apparently from a radiant in Gemini or Orion. From $13^h\ 15^m$ to $13^h\ 45^m$ three meteors were seen—one a Leonid of the fourth magnitude which was moving east. From $15^h\ 10^m$

to $15^h\ 30^m$ five small ones were seen; one of these was probably a Leonid. From $15^h\ 50^m$ to $16^h\ 5^m$ five small meteors were seen all from Leo, but none from the radiant. They seemed to come from a point $10°$ or $15°$ west and north of the radiant. From $16^h\ 5^m$ to $16^h\ 25^m$ six were seen to come from the west of Leo, from the direction of Mars; only one came from the radiant. These were all swift and nearly all faint. From $16^h\ 55^m$ to $17^h\ 20^m$ three were seen; one from Leo — but not from the radiant — this one cut the handle of the sickle at right angles, and was going east. From $17^h\ 20^m$ to $17^h\ 40^m$ the sky was more or less hazy, and no meteors were seen.

Nov. 12. From $6^h\ 0^m$ to $9^h\ 10^m$ only one or two faint meteors were seen. None of these could have been from the radiant From $10^h\ 10^m$ to $10^h\ 25^m$ no meteors were seen. From $10^h\ 35^m$ to $10^h\ 50^m$ no meteors. Frequent watches up to $12^h\ 30^m$ when it clouded all over. Waited and watched until $18^h\ 0^m$ but the sky remained densely clouded.

Nov. 13. Cloudy, but from $6^h\ 30^m$ to $7^h\ 0^m$ the clouds thinned down, and then closed in again. At $7^h\ 45^m$ the sky was thick, but a few bright stars could be seen overhead for a few minutes. At $8^h\ 5^m$ the sky cleared for about ten minutes, but no meteors were seen. It clouded again and remained so as late as $18^h\ 10^m$, during which time no stars could be seen, though a watch was kept up all night.

Nov. 14. Densely clouded with frequent rain until $12^h\ 30^m$, when the sky began to clear.

At this time a few meteors were seen, mostly low in the northwest near Alpha Cygni. That these were Leonids was shown by the persistent streaks they left and by their direction of motion. From this time the meteors gradually increased in number. Several hundreds were seen until towards daylight. They seemed to increase until between 15 hours and 16 hours when the maximum seemed to occur. After that time many meteors were seen, but the shower was noticeably over before daylight approached.

The meteors came in spurts; for a few minutes none would

be seen, then there would follow a flight of half a dozen or more, coming in quick succession, and moving more or less in the same direction.

One striking feature was the entire absence of any meteors at the radiant; very few were seen anywhere near it, and these were mostly small ones. In general the first appearance of a meteor was from 90° to 100° from the radiant, and many of them made their appearance at a much greater distance than this. If a person had confined his view to within a radius of 20° from the radiant, he would not have known anything out of the ordinary was in progress, and if throughout the display he had kept his watch to the east of the radiant he would scarcely have seen a meteor.

A few meteors identical in color and streakiness with the others, seemed to pass at a distance as much as 10° from the radiant.

There was a large percentage of bright meteors, that is, attaining the first magnitude. There were no very great ones however, only one attaining anything near the brightness of Venus.

The meteors were all white, with very rapid motions, leaving beautiful greenish or bluish streaks, which persisted for a large fraction of a second. None of the meteors appeared to explode; they simply rapidly increased in brilliancy as if forcing their way through a dense resisting medium.

Mr. G. W. Ritchey, who observed most of the time with Mr. Ellerman and myself, has kindly supplied me with the following counts of the meteors seen by him from $14^h\ 55^m$ up to $17^h\ 25^m$ from frequent watches; to this is added the hourly rates derived from the counts. These show that the maximum was past by $16^h\ 0^m$.

There is one point, however, that has since occurred to me that might seriously affect a determination of the time of actual maximum of the shower. I have already stated that the majority of the meteors were seen far to the west of the radiant. As the radiant ascended towards the meridian, as morning approached,

the visible region of meteors would pass below our horizon to the west, and an apparent diminution in the counts would result This, of course, would not affect the northerly meteors; but those in the north were always few compared to those in the west. Though this cause might produce an early apparent maximum of meteors, it should also have caused the meteors to be more plentiful in the early watches, if the shower was then in full force. I feel, therefore, pretty certain that the shower was not far advanced when it cleared here.

COUNTS OF METEORS BY G. W. RITCHEY.

											Hourly rate
From 14^h	55^m	to 15^h	5^m.	Meteors	seen,	7,	of which	$1 = 1$st	mag.		42
15	5	" 15	15	"	"	8	"	$1 = 1$	"		48
15	15	" 15	25	"	"	15	"	$1 = 1$	"		90
15	25	" 15	33	"	"	9	"	$3 = 1$	"		67
15	33	" 15	45	"	"	21	"	$1 = 1$	"		105
15	45	" 16	5	"	"	8	"	$2 = 1$	"		24
16	5	" 16	25	"	"	26	"	$2 = 1$	"		78
16	53	" 17	10	"	"	15	"	$0 = 1$	"		53
17	10	" 17	25	"	"	8	"	$0 = 1$	"		32
17	25	" 17	45	"	"	11	"	$3 = 1$	"		33

During these counts Mr. Ritchey saw two small meteors in the southeast within ten minutes' time of each other, and in the same region, which had a slow undulating motion, as if whirling end over end in their flight through the atmosphere.

At 17^h 17^m a meteor equal to Venus left a bright train a little north of Capella which remained visible for two or three minutes, and in this time gradually drifted towards the north. During the observations I recorded the paths of thirteen meteors, which indicate a radiant at R. A. $= 9^h$ 56^m; Declination $= + 24°$.

In every respect this was the finest display of meteors I have yet seen.

Preparations had been made to try and photograph the meteor trails. Though a great number of plates were exposed for intervals of something like twenty minutes each, from 13^h 40^m to 17^h 45^m no trails were secured. This in itself was a dis-

appointment, but the result was not unexpected when the shower was over, for though a watch was kept on the regions covered by the cameras no bright meteors were seen to cross their fields of view.

The plates used were Cramer "Crown," which are rapid plates. The development was very carefully done, and though each plate showed a great number of star images no meteor trails were found.

The flight of the meteors was very rapid—too rapid for the smaller ones to leave trails, and no large ones crossed the plates.

Five cameras, a 6¼-inch, three 4½-inch lenses by Brashear, and one 3½-inch, were fastened to an ingenious polar axis contrived by Mr. Ellerman from a combination of the equatorial mounting of the 24-inch Ritchey reflector, the clockwork of the 12-inch Brashear refractor, and some heavy boards to extend the polar axis, and a couple of wooden trestles to support the upper end of the wooden portion of the polar axis.

The cameras were so arranged that the 6¼-inch could be pointed at the radiant and the others to different parts of the sky north and south and west of the radiant, so as to cover as wide a region as possible. Two of these cameras carried 8×10 plates, one a $6\frac{1}{2} \times 8\frac{1}{2}$, and the two others 5×7 plates.

The original program was to change the entire series of plates every ten minutes, but the relative scarcity of meteors showed this was unnecessary, and the changes were made about every twenty minutes.

From the fact that the most barren region of meteors was that of the radiant it was decided to throw the whole system of cameras more to the west in the direction in which most meteors were seen. In all some forty-five exposures were made.

The star images on these plates are not good, because of the instability of the mounting when loaded with all the cameras, but this, of course, would have no deteriorating effect in photographing the path of a meteor.

I am very much indebted to Messrs. Ellerman and Ritchey

for help on the night of the 14th, and a general interest throughout the observations.

Though the photographic results were discouraging, I have much faith in the method, and this has been strengthened by the results at Harvard and Yale.

I have already shown (*Popular Astronomy* No. 46, **5**, 281) that I do not think the presence of the Moon at the coming November shower of these meteors will materially interfere with photographic observations of them where the exposures are not too prolonged. The Moon must seriously interfere, however, with the visual observations, and the grandeur of the display as a spectacle will be more or less lost in the bright moonlight.

The watch for meteors was continued at frequent intervals throughout the night on November 15, when time permitted from other work. The radiant appeared to be perfectly dead, and no Leonids were seen. One small meteor was seen at $15^h\ 5^m$ which might have been a Leonid.

On this date the great telescope was turned to the radiant, and two nebulae, not in the *N. G. C.* were found

1) 1860.0 $\alpha = 9^h\ 55^m\ 4^s$; $\delta = +22°\ 22.0'$ F. Elongated.
2) 1860.0 $\alpha = 9\ 55\ 15$; $\delta = +22\ 21.5$ S. v. F. Elongated.

The positions are estimated from stars near, but will be fairly close approximations.

On November 16, no meteors were seen that could be traced to the radiant.

The times in all the observations are six hours slow of Greenwich. The Andromedes were looked for on November 22, 23, 24, and 26. The 27th and 28th were cloudy. Nothing was seen of these meteors.

YERKES OBSERVATORY,
March 2, 1899.

PHOTOGRAPH OF THE MILKY WAY NEAR THE STAR THETA OPHIUCHI.

By E. E. Barnard.

One of the most remarkable and singular regions photographed with the six-inch Willard lens during my connection with the Lick Observatory is that shown in the present picture (Plate II).

To the naked eye Theta Ophiuchi occupies a rather dull region of the Milky Way, which is perhaps made more obscure by the brilliant star clouds southeast of it. If one examines this region with the naked eye, he will see a long dull vacancy, running east and west, to the south of Theta; otherwise the naked eye sees nothing remarkable in the immediate vicinity of the star. The photograph, however, shows that this region is very remarkable, and that certain features shown here do not seem easily explainable without the assumption that the entire groundwork of the Milky Way at this point has a substratum of nebulous matter, though I must confess that it does not look entirely like nebulosity on the plate.

As will be seen, the great dark strip, which is faintly visible to the naked eye, is shown to be an irregular rift in the sheeting of stars, and extending not only south but to the east and north of Theta. North of that star it breaks up into irregular dark apertures, and extends in a straggling manner to the western edge of the plate, from whence, my photographs show, it extends in a broken manner to the wonderful nebulous region about Rho Ophiuchi, and is connected with the southerly and most distinct of the great vacant lanes near that star.

The peculiarity which I have suggested might imply a nebulous background here, is the singular feature of dark details in the dark rifts and apertures, which are nowhere so remarkably shown as in this plate, though they are noticeable in the vacan-

cies near Rho Ophiuchi and to the east of the present plate (near 58 Ophiuchi). However, this region, from Rho Ophiuchi to a few degrees beyond 58 Ophiuchi, may be considered as one and the same region, for it is singularly different from any other portion of the Milky Way. Just north of Theta Ophiuchi is a small sharply defined S-shaped aperture in the mass of stars that looks almost like a defect, so distinct does it appear.

These peculiar dark apertures strongly remind one of the appearance sometimes presented in the umbra of Sun-spots, where a darker hole lies in the dark central spot, as if the cavity were partly veiled with some sort of medium that itself had apertures in it—or a hole within a hole.

An earlier photograph of nearly this same region was published in the *Photographic Times* for August 1895, but I think the present picture, which has never before been reproduced, shows the peculiarities of this part of the sky considerably better than the previous photograph.

YERKES OBSERVATORY,
March 2, 1899.

REDUCTION TO THE SUN OF OBSERVATIONS FOR MOTION IN THE LINE OF SIGHT.

By FRANK SCHLESINGER.

SPECTROSCOPIC observations for motion in the line of sight are said to be reduced to the Sun when they have been corrected for whatever motions the observer has had with respect to the Sun. These motions fall under two heads;

1. That due to the diurnal rotation of the Earth.

2. The motion of the Earth as a whole, including not only its elliptical motion but also the effects of perturbations.

The first of these motions is easily eliminated; let

α, δ, be the mean right ascension and declination of the star.

ϕ, the latitude of the observer.

t, the sidereal time.

Adopting the usual convention by which approach is denoted by the negative sign and recession by the positive, we have the following correction in kilometers per second to be added to the observed velocity:

$$[9.666] \sin (t - \alpha) \,.\, \cos \delta \,.\, \cos \phi \,.$$

For a fixed station ϕ is constant and this correction, which has a maximum value of only 0.46 kilometers per second, may be conveniently tabulated with $(t - \alpha)$ and δ as the arguments.[1]

In order to calculate the effect of the Earth's motion as a whole, let

ΔX be the component of this motion in a direction parallel to the line of equinoxes.

ΔY, the component perpendicular to ΔX and parallel to the plane of the equator.

ΔZ, the component perpendicular to plane of the equator.

All the principal ephemerides tabulate the values of the Sun's

[1] See W. W. Campbell's paper in *Astronomy and Astro-Physics*, **11**, 319 (April 1892).

equatorial rectangular coördinates for every twelve hours in the year. In addition the Berlin *Jahrbuch* has since 1896 given the differences of these coördinates at 3 hours and 15 hours of each day, Berlin Mean Solar Time. It is evident that these differences may be regarded as the component velocities defined above, in which the unit of time is twelve hours and the unit of length is the mean radius vector of the Earth's orbit. ΔX is positive from September 22 to March 21, and negative during the other half of the year. ΔY and ΔZ are positive from December 21 to June 21.

The correction to be added to the observed velocity is

$$[3.5392_n]\,(\Delta X \,.\, \cos\alpha \,.\, \cos\delta + \Delta Y \,.\, \sin\alpha\cos\delta + \Delta Z\sin\delta).$$

The factor $[3.5392_n]$ serves to reduce the correction to kilometers per second and was computed with 8.80″ as the solar parallax. A change of 0.01″ in this constant would correspond to a maximum change of 0.03 kilometers per second in the correction; this is the greatest, and indeed practically the only source of uncertainty in the above formula.

In interpolating between the *Jahrbuch* values of ΔX, etc., for the moment of observation the nearest half hour will be sufficient. A difference of 30 in the last two places of decimals corresponds to only 0.01 kilometers per second. The accompanying table is intended to facilitate the interpolation. The hourly changes in ΔX, ΔY and ΔZ are given at intervals of ten days. This table may be used in any year whatsoever, until the accuracy of these observations shall surpass 0.01 kilometers per second.

		Hourly change in		
		ΔX	ΔY	ΔZ
January	1	12	57	25
"	11	23	55	24
"	21	33	50	22
"	31	42	44	19
February	10	49	36	16
"	20	55	28	12
March	2	59	18	8
"	12	62	8	4
"	22	62	0	0

		Hourly change in		
		ΔX	ΔY	ΔZ
April	1	60	11	5
"	11	57	21	9
"	21	52	29	13
May	1	46	36	16
"	11	38	43	19
"	21	30	48	21
"	31	20	52	22
June	10	10	54	23
"	20	0	55	24
"	30	9	54	23
July	10	19	52	23
"	20	28	49	21
"	30	36	44	19
August	9	44	38	17
"	19	50	30	14
"	29	55	22	10
September	8	58	13	6
"	18	61	4	2
"	28	61	5	2
October	8	60	15	6
"	18	56	25	10
"	28	51	33	14
November	7	44	41	18
"	17	36	48	21
"	27	26	53	23
December	7	15	57	25
"	17	5	58	25
"	27	6	58	25
"	37	18	56	25

NEW YORK, March 4, 1899

ON A NEW TYPE OF TELESCOPE OBJECTIVE ESPECIALLY ADAPTED FOR SPECTROSCOPIC USE.

By CHARLES S. HASTINGS.

THE ordinary achromatic doublet, as invented by Dolland in the last century, is, as is well known, very far from complying with the condition implied in its name. For telescopes of small aperture, or even for those of very considerable aperture, if a ratio of focal length to aperture as great as that customary with Dolland be employed, the defect in color correction is neither very conspicuous nor very harmful in their ordinary use. But if the apertures are very large, as in our modern astronomical instruments, or if the length be reduced relatively to the diameter of the objective, this defect of secondary color aberration becomes very conspicuous and reduces the optical efficiency of the instrument very materially. The maximum inconvenience of the defect, however, falls upon the spectroscopist, who finds that, although the optical efficiency of his instrument is independent of the wave-length of light which he happens to be observing, the instrumental adjustments must undergo frequent changes for adaptation to different portions of the spectrum. Another familiar and obvious consequence of the secondary color defect is the impracticability of adapting the same instrument to purposes of both eye and photographic observation.

It follows, therefore, that the solution of the problem, first seriously undertaken, I think, by Fraunhofer, namely, to devise an absolutely color-free objective, is, and has long been, of continuously increasing moment. Fraunhofer failed; but unless I greatly misapprehend the meaning of his own record of his work, the effort led directly to the discovery of the Fraunhofer lines and to the beginning of spectroscopy. It is true that nowhere, as far as appears in his published writings, does he state that this was his aim; but in view of his very extended experi-

ments in varying the constitution of his glasses, of his studies of the minute dispersion characteristics of various substances, and of the extraordinary skill and conscientiousness in perfecting an instrument which has possessed no other error of importance since his unequaled contributions to the art of telescope making, few will question the validity of the inference.

Doubtless many investigators since Fraunhofer's time have attacked the same problem, but, so far as I am aware, without any recorded success until the writer showed, in a paper published in the *American Journal of Science*, Vol. XVIII, p. 429, that there were certain glasses, unfortunately not then procurable, which would yield, in a triple combination, an objective entirely free from color. Since then the extraordinary increase in number of materials at the command of the optician, resulting from the labors of Dr. Schott, of Jena, led the writer to return to the problem, with results which were published in a paper in Vol. XXXVII of the same journal, in 1889. A general method of dealing with all such problems was then developed and a number of triads were indicated which would yield the most favorable results. It is true that those given included a phosphate glass which was believed by the makers to be permanent and has since proved not to be so; but it was distinctly stated that the table exhibited a considerable number of other promising combinations, and the general method of recognizing them was pointed out.

It may properly be stated here that the latter paper also contained a general discussion of interesting double combinations, one of which promised to be of great value to spectroscopists; but the inability of glassmakers to supply large disks of the materials in question proved an unforeseen difficulty. Still, the writer employed this construction for a number of years for his spectrometer, and only displaced it recently by an improved type of objective. Professor Keeler has also employed the same construction, made by Mr. Brashear with my aid, satisfactorily in spectroscopic work.

The experiments with triple combinations which followed

the paper last named met with an unforeseen difficulty. The particular triad which promised most in theory proved to have one of its numbers a perishable glass. This might possibly have been used by covering the objectionable material by a more permanent glass cemented to it, but this course is not without risk, and certain defects to be noted later are not so readily eliminated if this method be chosen. The only practicable course seemed to lie in replacing this material by one beyond suspicion, and much time was spent in investigating the possibilities of this means. It was found, as appears from the paper cited above, that there was no difficulty in selecting triads which would meet the analytical condition, insuring complete diminution of color and subject to practical limitations as regards permanency; but the necessarily greater curvatures of the lens surfaces introduced a new source of imperfection, namely, chromatic difference of spherical aberration. Of course, this, like all other errors, is present to a greater or less degree in all optical instruments which depend in any way upon refraction for their action. In telescopes, however, this error has never been sufficiently great to betray itself to the users, although clearly indicated by theory. Gauss, indeed, a long time ago, showed how to reduce this particular error to a residual of a higher order of minuteness, but the fact that his construction has never come into use is a most convincing proof that the error is quite negligible as compared to other defects inherent in the ordinary construction. But when we try to make a color-free triple objective after the methods of the paper of 1889, we find that the defect in question becomes of great moment. Especially is this true if we prescribe the cementing of the objective so that there shall be only two free surfaces. Such an objective, if corrected as regards spherical aberration for light-waves of mean length, would have strong positive spherical aberration for the red, and negative for the violet ends of the spectrum. It is true that this defect might not prove very obvious for a telescope which is to be used only for objects which are approximately white, but it would be intolerable in spectroscopic use. The obvious method of

reducing the error is to increase the ratio of the focal length to the aperture. This method, however, would introduce such serious structural and mechanical difficulties, and so far reduce the convenience of handling all spectroscopes to which it might be applied, that it seemed to me quite impracticable.

As a possible means of securing the end in view, convinced as I am that its importance warrants any amount of labor, I lately turned to a consideration of the possibilities possessed by a combination of four varieties of glass. The investigation is necessarily somewhat laborious, as appears from the unusual conditions imposed from the outset; but the time expended in attaining complete success was short, compared to the protracted investigations which led to a definitive rejection of the triplet as quite inadequate. In short, I have constructed an objective, consisting of a quadruple combination of silicate flint, borosilicate flint, silicate crown and barium crown, which possesses all the properties demanded. It has but two free surfaces, the four lenses being cemented together. With an aperture of one tenth the focal length, its focal plane is rigidly the same for all wave-lengths, from that of the Fraunhofer line A to that of K, while it is sensibly free from chromatic differences of magnification and of spherical aberration. With its perfect color correction, the well-known (but ordinarily overlooked) chromatic aberration of the eye becomes very sensible. This, however, I have eliminated by means of a specially devised ocular, so that, in my instrument, there is no reason why its length may not be made permanently invariable. One notable advantage in the construction will appear at once to all spectroscopists: wave-surfaces from the collimator being rigidly plane for all wave-lengths, the adjustment of the prisms for minimum deviation — provided always that their faces are accurately plane — ceases to be of importance. Thus a construction, which must have occurred to every-one who has seriously studied the theory of the spectroscope, and in which the last prism of a train is of half the angle of the remainder, and silvered on the back so that the light retraces its course through the train, becomes entirely practical. Indeed,

my experiments with the new telescope lead me to prefer a construction of spectroscope in which the collimator and telescope are set at constant angle, and the prisms, arranged as above, are alone movable. This is the familiar construction of the grating spectroscope.

Although the objective described above consists of four lenses, I imagine that a cemented system of five lenses would in some cases be preferable, especially in relatively large apertures; but there is no doubt in my mind that four kinds of glass are sufficient, and, unless greater structural complexity is admitted, necessary for the ends defined.

Should the construction meet my confident expectations and supply the spectroscopist with an optical instrument combining the merits of a reflector, with the greater merits of a refractor, it will be convenient to give it a characteristic name suggested by its properties. These are, as given above, chromatic differences of focal distance, of focal length, and of spherical aberration, all reduced to practically zero, together with a minimum possible number of free surfaces. As such an objective is the same in its action upon light of all wave-lengths, I propose to call it an *isokumatic* system.

Mr. Brashear, of Allegheny, who made for me the prisms for the study of these glasses, as well as scores of others, and whose unfailing good nature and constant readiness to lend me his efficient aid have greatly facilitated all my optical investigations, merits my unstinted acknowledgments. I have promised the necessary calculations if he is called upon to carry out for others a difficult piece of optical work which has yielded so much satisfaction to the writer.

Yale University,
March 1899.

REMARKS ON THE METHODS EMPLOYED IN THE DETERMINATION OF THE RADIAL VELOCITIES OF THE STARS.[1]

By H. Deslandres.

Professor Vogel, Director of the Potsdam Observatory, has recently published in the *Astronomische Nachrichten* (No. 3483, March 1898) and the Astrophysical Journal (April 1898) a paper entitled "Fehlerquellen bei den Untersuchungen über die Bewegung der Sterne im Visionsradius." This article, which has just been brought to my attention, is devoted to a critical discussion of a paper published by myself in the *Bulletin Astronomique* (February 1898) entitled "Causes d'erreur dans la recherche des Vitesses radiales des astres. Importance de l'erreur de temperature. Methodes de correction." In this paper I have presented the results of my own investigations on the cause of errors in the measurement of radial velocities due to temperature variations, adding a few remarks on the means employed at Potsdam and at Paris to correct or eliminate them. But judging from the tone of his reply, Professor Vogel has taken offense at these remarks; and as he seems to me to have exaggerated or imperfectly understood their bearing or their purpose, I beg permission to present a few explanations in order to render my statement more definite and complete.

At the outset I wish to state that I have the greatest admiration for the work of the Potsdam Observatory, and particularly for the investigations relating to the radial velocities of the stars. I have read with the greatest care and profit the various memoirs on the question, as well as Vol. VII (parts I and II) of the Publications of the Observatory, which Professor Vogel nevertheless charges me with not knowing. But, having studied the question myself, in several particulars my ideas and my results are not exactly the same as those of Professor Vogel.

[1] Translated from *A. N.*, No. 3530, at the request of the author.

A variation in the temperature of the air in general produces a change in the index of the prisms of the spectroscope, and consequently a displacement of the spectrum, which is frequently of the same order as the displacement due to motion. This source of error does not affect visual determinations of radial velocity; but in the photographic method, which Professor Vogel was the first to adopt, it is important, since the exposure for the star equals or even exceeds an hour.

Professor Vogel briefly describes this source of error in the second half of page 24 of Vol. VII, and this statement is reproduced complete in his recent article. His conclusion is as follows: "Changes of temperature can have no influence on the relative positions of the stellar and comparison lines when, as in actual practice, the comparison source acts during the entire exposure of the star, or at intervals symmetrical with respect to the middle of the exposure."

For my own part, I have also studied with the greatest care the effect of a change of temperature during the exposure, and I have even employed a new method, based on the use of reference spectra, which gives the exact displacement due to the change of temperature during the exposure of the star. This displacement, with the spectroscopes employed at the present time corresponds, for a temperature change of 1°, to an average radial velocity of about 14km per second. It varies with the nature of the prisms, and depends upon the precautions taken to protect them against changes of temperature. As a result of this experimental study we are led to distinguish in stellar spectroscopes an important quality, viz., the particular sensitiveness of the spectroscope to variations of temperature.

My conclusion, which differs from that of Professor Vogel, is as follows: Variation of temperature during the exposure is, under present conditions, the weak point of the photographic method; for it is difficult to avoid and to completely correct. It stands in the way of long exposures which, in ordinary stellar photography, have given such excellent results. In general, it is the principal obstacle to great precision of measurement.

In support of this statement an immediate and general proof may be submitted. Even with carefully protected prisms the stellar spectrum is slightly broadened as a result of temperature changes. But when the lines become diffuse and lose their sharpness the fine lines frequently disappear; and these are precisely the lines which can be measured most accurately. Undoubtedly, in the case of the broad hydrogen line of the white stars (Class I), which Professor Vogel employs in measuring the displacement, the broadening due to temperature is unimportant; but these same spectra contain fine lines, those of iron for example,[1] which are susceptible of more precise measurement, and which are affected by temperature changes.

Other causes of error which also depend upon the temperature have a direct effect in modifying the interval to be measured between the two widened lines. The method of using a terrestrial source adopted by Professor Vogel may introduce an error of this kind. The luminous beams of the two sources to be compared are very different in the spectroscope. One is reduced to a plane triangle which traverses the central section of the prisms, while the other is a solid cone with circular base. Now prisms are poor heat conductors, and the center of the prisms differs in temperature and index from the edges. If the distribution of temperature within the prisms is not symmetrical with reference to the central section, either from the manner of supporting the prisms or from an accidental cause, there may result a displacement of one line with reference to the other. For this and various other reasons it seems to me preferable to give the same aperture to the two beams which are to be compared.

The arrangement adopted for the exposures of the two sources may also introduce small errors of a similar nature. Professor Vogel holds that the distance between the two widened lines is not affected when the terrestrial source is used during the whole exposure of the star. But in this case the intensities of the two sources must preserve a constant ratio, or, practically,

[1] I recall the fact that I was the first to announce the great advantages to be derived from the use of the iron lines. *Comptes Rendus*, **112**, 413, February 1891.

remain constant; and this condition is not always realized. If the star is not on the meridian (and it is very difficult to observe it always in this advantageous position) its brightness varies with the time; the transparency of the air also occasionally undergoes variations which, though hardly sensible to the eye, are considerable with the blue and violet radiations. Moreover, may not the hydrogen Geissler tube, illuminated during a whole hour, be subject to changes arising from gradually evolved gases or irregularities in the interrupter of the coil? The constancy of the Geissler tube requires special precautions.

Further, Professor Vogel uses the terrestrial source at intervals symmetrical with respect to the middle of the exposure of the star.[1] But this single condition is not sufficient; in my opinion it is also necessary to have the middle of each half-exposure of the terrestrial source coincide with the middle of each successive half of the star's exposure. In fact, if the temperature varies proportionally to the time, it is necessary and sufficient to make the middle of the exposure of the terrestrial source coincide with the middle of the exposure of the star. The same thing also holds, if the time of exposure of the star is very short, occupying only a few minutes, when the change of temperature is not proportional to the time. In the latter case, but with a long exposure of the star, an hour for example, it is necessary and sufficient to divide the star's exposure into successive equal parts, and to make the middle of an exposure of the terrestrial source, equal for every part, fall at the middle of each of these parts.

Professor Vogel favors placing the two half-exposures of the terrestrial spectra at the beginning and end of the star's exposure, which has a duration of an hour. It would be better to make the middles of these half-exposures come 15^m and 45^m from the beginning. As in Professor Vogel's simple arrangement the two sources can work together without interfering with one another, this modification would be very easy to realize.

[1] PROFESSOR VOGEL does not give the customary length of each of these half-exposures.

Further, Professor Vogel's two half-exposures superpose their effects, and it is necessary to make them exactly equal.

The arrangement that I have adopted in my own work, which consists in the use of auxiliary iron reference spectra, was described in 1894 (*Comptes Rendus*, **119**, 1222) and subsequently adopted without material modification by Mr. Newall (*Monthly Notices*, June 1897). I divide the star's exposure of one hour into three equal parts of 20 minutes each, so that the middle of the exposures of the terrestrial source must take place 10^m, 30^m, and 40^m from the beginning respectively. Moreover, the three exposures of the terrestrial source (of 2^m each) do not superpose their effects, but give three juxtaposed spectra. This has the great advantage *of registering the displacement due to the temperature during the exposure, and of permitting the application of a suitable correction* if the variations are different in the two halves of the exposure. Moreover, this method makes it possible to judge more correctly of the true sharpness of the stellar spectrum than the plan followed at Potsdam.

Nevertheless I have been led in practice to make the three auxiliary exposures of iron at the beginning, middle, and end of the star's exposure, because the spectroscope employed at Paris with the great reflector is eight meters from the observer, so that the exposure of the star must be stopped in order to make the exposure of the terrestrial source. But as the three auxiliary iron spectra are juxtaposed and not superposed, it is possible to determine from the displacements at the observed temperatures the values they would have if the exposures had been made at 10^m, 30^m, and 50^m, as demanded by theory, and thus to make the final correction. In my preceding paper I have not given all these details, which are necessary for an exact understanding of the ideas which have guided me and the final arrangement adopted.

Summing the matter up, variations of temperature during the exposure introduce serious difficulties and diminish the precision of the measurements. I have sought to eliminate this disturbing influence in two principal ways, by rendering the

temperature of the spectroscope constant during the exposure, and, on the other hand, by making a spectroscope insensible to temperature changes.

In order to render the temperature constant I have employed successively automatic electric heating of the spectroscope and a continuous circulation of water around the apparatus. The variation has been diminished, but not altogether eliminated; it would nevertheless be possible to do much better in this direction. Quite recently Professor Lord has announced[1] that he has employed electric heating with advantage at the Emerson McMillin Observatory.

In my opinion a better solution is to construct a spectroscope insensible to temperature variations with M. Guillaume's ferro-nickel alloy and prisms of zinc crown. Four prisms of this material, the index of which does not change with the temperature, of 66° refracting angle, with telescopes having focal lengths of from 0.60m to 0.80m,[2] would give a dispersion at least equal to that of the Potsdam and Paris spectroscopes.

As with the four prisms the collimator and camera are nearly parallel, the entire spectroscope would be contained in a long narrow tube, of small dimensions, which would be free from all flexure if suspended at its middle point. In the present state of the subject such a spectroscope would seem to me to offer great advantages.

This discussion shows that the measurement of the radial velocity of the stars by the photographic method is still susceptible of marked improvement. If complete insensibility to temperature variations can be realized, and if, moreover, it becomes possible to make sensitive photographic plates of sufficiently fine grain to permit a magnification of the image as great as in visual observations, the limit of precision imposed by the optical constants of the spectroscope employed will be nearly attained.

[1] This JOURNAL, August 1898, p. 65.

[2] In determining the focal length of the collimator it is necessary to take account of the aperture and focal length of the astronomical objective, in such a way as to avoid having too large prisms.

Minor Contributions and Notes.

A NEW SATELLITE OF SATURN.

A NEW satellite of the planet Saturn has been discovered by Professor William H. Pickering at the Harvard College Observatory. This satellite is three and a half times as distant from Saturn as Iapetus, the outermost satellite hitherto known. The period is about seventeen months, and the magnitude fifteen and a half. The satellite appears upon four plates taken at the Arequipa Station with the Bruce Photographic Telescope. The last discovery among the satellites of Saturn was made half a century ago, in September 1848, by Professor George P. Bond, at that time director of the Harvard College Observatory.

EDWARD C. PICKERING.

HARVARD COLLEGE OBSERVATORY.
March 17, 1899.

NEW NEBULAE AND NEBULOUS STARS.[1]

MUCH care and skill are required to obtain the best results with the Bruce photographic telescope. Dr. De Lisle Stewart, who has had charge of this instrument for the last year, has succeeded in obtaining nearly circular images even when the exposures extended over several hours. He has recently found an interesting group of nebulae, hitherto unknown, within the limits of right ascension, $3^h\ 10^m$ to $3^h\ 50^m$ (1900), and declination, $-49^\circ\ 50'$ to $-53^\circ\ 40'$ (1900). A comparison of two plates, A 3339, and A 3346, taken on October 14, and October 20, 1898, respectively, with exposures of four hours each, shows the presence of the objects given in the following table. The current number assigned to each object is given in the first column, the approximate right ascension and declination for 1900, in the second and third, and a brief description of the object in the fourth column. The letters n, s, p, and f, in the fourth column are used to indicate north, south, preceding, and following, respectively.

[1] *Harvard College Observatory Circular* No. 38.

Number	R. A. 1900	Dec. 1900	Description
	h m	° ′	
1	3 10.0	−50 58	2 faint elong. neb.
2	13.7	−51 1	Elong. n to s, small.
3	16.0	−49 57	Spiral?
4	16.7	−51 3	Elong. n to s.
5	17.2	−52 33	Double, elong. sp to nf.
6	19.4	−53 33	Elong. n to s.
7	21.4	−53 4	Stellar.
8	21.7	−51 5	Stellar.
9	21.7	−51 3	Stellar.
10	21.8	−50 55	Stellar.
11	22.1	−52 3	Elong. stellar.
12	22.3	−51 37	Elong. np to sf, stellar.
13	22.3	−52 3	Elong, stellar.
14	22.3	−52 5	Very faint.
15	22.5	−51 37	Elong. np to sf.
16	22.9	−51 41	Elong. n to s.
17	22.9	−53 8	Ellip. elong. sp to nf.
18	23.1	−50 22	Stellar, elong. spiral?
19	23.5	−51 40	Stellar, elong. np to sf.
20	24.4	−53 22	Perhaps double star.
21	24.8	−51 25	Elong. p to f.
22	24.8	−52 29	Neb. star.
23	25.2	−53 1	Stellar, elong. n to s.
24	26.5	−52 59	Stellar.
25	26.6	−52 58	Stellar.
26	27.6	−50 40	Stellar.
27	27.7	−50 39	Spiral?
28	27.7	−50 37	Star prec.
29	28.1	−50 46	Elong. np to sf.
30	28.3	−53 29	Elong. sp to nf.
31	28.6	−52 15	Fine small spiral.
32	29.4	−52 47	Elong. sp to nf.
33	29.9	−51 47	Stellar.
34	30.2	−50 45	Elong. np to sf.
35	30.9	−53 30	Elong. p to f.
36	31.2	−51 39	Stellar.
37	31.8	−50 58	Stellar.
38	33.2	−52 58	Elong. p to f.
39	33.6	−52 18	Elong.
40	33.6	−52 19	Elong.
41	33.7	−49 54	Elong. np to sf.
42	34.1	−50 29	Elong. n to s.
43	39.1	−51 17	Stellar.
44	41.9	−51 51	Stellar, elong. sp to nf.
45	42.3	−51 19	Stellar.
46	43.0	−51 58	Elong. n to s.

Only two nebulae are given, in this region, in Dreyer's *New General Catalogue*. *N. G. C.* 1311 is identical with No. 5, and *N. G. C.* 1356 is identical with No. 27.

It will be noticed that four of these nebulae appear to be spiral.

No. 3 is described as "bright elongated center, faint nebulous wisps in ellipses or spiral." No. 18 "stellar nucleus with elliptical nebulosity sp." No. 27 "Faint nebulous star surrounded by nebulosity. One wisp has spiral tendency. Two nebulous stars sp and sf, very close to main nebulosity." No. 31, "Very fine small spiral nebula with two branches."

A bright meteor trail appears on Plate A 3346.

EDWARD C. PICKERING.

January 31, 1899.

A NEW FORM OF PHOTOGRAPHIC TELESCOPE.[1]

A GREAT number of very large telescopes of nearly the same form have been given to observatories during the last few years. Although such instruments are indispensable, in a limited number of investigations, yet when the latter are divided among so many telescopes the results obtained by each are often disappointing to the donors. These instruments have been erected, with two or three exceptions, in places selected from local or political motives, and without regard to meteorological or astronomical conditions. For this reason, the great observatories of the world are near large cities or universities where the very conditions that have rendered the countries great have rendered them unfit for the most delicate astronomical research. Nine tenths of these instruments are in the temperate zone in Europe and the United States, while the southern hemisphere has been entirely neglected, and many of the most interesting parts of the southern sky have not yet been examined by a modern telescope of the largest size.

This duplication of expensive instruments in unsuitable localities is rendered still more objectionable by another condition. All the telescopes are similar in form, their focal length being from 15 to 18 times the aperture, and therefore, all are best adapted to the same kind of work. In view of these numerous precedents it was a bold step to deviate from it. But this step was taken, and taken by a woman, Miss Catherine W. Bruce, of New York, who gave $50,000 to the Harvard College Observatory to construct a telescope of 24 inches aperture, in which the focal length should be only six times the aperture. Fortunately, this experiment succeeded, and the Bruce Photographic Telescope is mounted in Arequipa, Peru, in a climate unsurpassed, so far

[1] *Harvard College Observatory Circular* No. 39.

as is now known, for astronomical work. Its immediate results are charts, each covering a large part of the sky and showing such faint stars that 400,000 appear upon a single plate. By its aid, many new stars of the peculiar fifth type have been found in the Large Magellanic Cloud, showing an additional connection of this object with the Milky Way. A group of forty nebulae, hitherto unknown, has been found in another part of the sky. The most important work of the Bruce telescope, however, is that every year it sends hundreds of photographs to the great storehouse at Cambridge. Besides the immediate discoveries made from these plates, they doubtless carry with them many secrets as yet unrevealed, and many images of objects of the greatest interest yet to be discovered. A striking example of this kind is found in the recent discovery of the planet Eros, which, next to the Moon, is sometimes our nearest neighbor in the heavens. Calculation showed that this planet must have been near the Earth, and therefore bright, in 1894. An examination showed that this object, although not discovered until 1898, had not escaped the Harvard telescopes. Two images of it were found upon the Bruce plates, fifteen upon the Draper plates, and three upon the Bache plates. It can thus be followed through nearly half a revolution. Six images were also obtained in 1896, when it was more distant and much fainter.

These examples show the advantages of trying new forms of telescopes instead of duplicating those now existing. The Bruce telescope is well adapted to investigations in which the focal length is small. It will therefore be interesting to try the effect of a great focal length. It is proposed to build a telescope with an aperture of 12 to 14 inches, and a focal length of 135 or 162 feet. This telescope would probably be placed horizontally and the star reflected into it by means of a mirror; the motion of the Earth would be counteracted by moving the photographic plate by clockwork. It would thus become a large horizontal photoheliograph. This method of mounting a telescope for use on the stars was advocated by the writer in 1881, and has been used here since then with successive telescopes of 2, 4, and 12 inches aperture. The instrument here proposed would be adapted to investigations for which a great focal length would be needed, as the latter would be more than a hundred times the aperture. Several such investigations may be suggested, any one of which, if successful, would amply justify the construction of such an instrument.

1. *The Sun.*—The best instrument now in use for photographing the

Sun, the horizontal photoheliograph, is a small instrument of this form. It is possible that, under favorable atmospheric conditions, finer details on the Sun's surface could be obtained with a large instrument than have yet been photographed. It would be equally useful in photographing the protuberances. Preparations must soon be made for observing the Solar Eclipse of May 28, 1900. This instrument might be useful in photographing the spectrum of the reversing layer, and in showing the details of the inner corona.

2. *The Moon.*—The images of the Moon obtained with such a telescope would be more than a foot in diameter, and even if printed without enlargement would probably surpass the best photographs yet taken. The use of a telescope of this form for photographing the Moon was advocated by Professor W. H. Pickering in 1894 (*Harvard Observ. Ann.*, XXXII, p. 110). It is possible that good results could also be obtained with Jupiter, Saturn, and perhaps Mars.

3. *Eros.*—This planet approaches the Earth so closely that its parallax sometimes amounts to a minute of arc. The next approach, in 1900, will be more favorable than any other until 1927. Careful preparations should, therefore, be made for observing Eros when east and west of the meridian, since the distance of the Sun can probably be determined with more accuracy in this way than by any method of observation yet attempted. As the distance of the Sun is the unit to to which all astronomical distances are referred, the importance of its accurate determination cannot be overstated. It is one of the great problems of astronomy which, though supposed in the eighteenth century to have been solved, must probably be left to the twentieth century for satisfactory solution. To determine the parallax from the Transit of Venus in 1874, the principal nations of the world sent expeditions to the most remote regions. In all, about eighty stations were occupied at an expense of more than a million of dollars.

4. *The fixed stars.*—It is expected that the positions of adjacent stars could be determined with this instrument with an accuracy approaching that of the heliometer. If so, it would have an important and permanent field of work in charting the coarser clusters, the double stars, and determining stellar parallax. Also in locating the major planets, and the relative positions of the satellites of Jupiter and Saturn with an accuracy as yet unattained.

The very moderate expenditure of $5000 to $10,000 would permit this experiment to be tried here, since we already have a portion of the

apparatus required. If successful, the name of the donor would always be honorably associated with a new departure in one of the most important branches of astronomy.

EDWARD C. PICKERING.

February 11, 1899.

PHOTOGRAPHING METEORS.[1]

VARIOUS plans have been considered by which all the meteors visible in a large part of the sky at Cambridge can be photographed. Such a plan does not seem impracticable or premature, in view of the large number of meteors photographed during the shower of last November. The simplest device consists in pointing a camera, having a wide angle lens, to the zenith. Two meteor trails were obtained in this way November 14, 1898. A Morrison wide angle lens of 8 inches focal length was used, and an 8 × 10 plate. Since then, plates have been exposed on several clear nights, and on the second night, January 7, 1899, a meteor was photographed. About one-third of all the meteors having long paths, and visible at a single station, pass within 30° of the zenith, and all of these, if bright, could thus be photographed. Our knowledge of very bright meteors is extremely limited. They are so few in number that we cannot determine their radiant points in the usual way, and unless they happen to be observed carefully from more than one station, little information is obtained regarding them. The radiant point can be determined by observations of a single meteor from two stations, as well as from the intersection of two meteor trails as seen from one station. Two such cameras have been constructed and will be in operation shortly at Blue Hill and at Cambridge. They are provided with caps actuated by alarm clocks, so that the exposure is stopped automatically shortly before dawn. The operator need only expose a plate in the evening, after dark, and remove and develop it at his convenience the next day. If, now, two photographs are obtained of the same meteor, much information will be furnished regarding it. Bright meteor trails often show points of increased brightness due to small explosions. Superposing the two photographs, the height of the meteor at the instant of explosion is given by a simple proportion. As the distance of the meteor on the two photographs is to the focal length of the lenses, so is the distance apart of the two stations, to the

[1] *Harvard College Observatory Circular* No. 40.

required altitude. A similar computation may be made from the distance apart and azimuths of the trails themselves, if no distinctive points appear on them. The positions of the trails in space can be determined if the plates are leveled, or from the trails of the stars which also appear on the plates. The intersection of the two trails gives the declination of the radiant point of the meteor, but its right ascension is indeterminate unless the time at which the meteor appeared is noted. This difficulty might be remedied by mounting the camera equatorially and it is possible that this plan may be adopted later.

The spectra of bright meteors could be obtained by placing a prism in front of the lens of the camera. In this case the value of the result would be greatly increased by giving a motion to the photographic plate. For instance, if a vibratory motion is given to the latter, like that of a pendulum, the image of the meteor as it traversed the plate would have a relative motion which would be continually varying. At one point it might become small, so that we should be virtually following the meteor by clockwork, as in the case of a star, and at this instant its spectrum would be photographed even if not very bright. If the period of vibration is a second, or less, two or more images of each meteor would appear at intervals equal to the time of vibration. This would give the angular motion of the meteor, and, if its distance is known, its absolute velocity.

By the expenditure of three plates a night it seems possible to determine the altitude, radiant point, velocity, and spectrum of one-third of all the bright meteors visible in a given locality. It is probable that several meteors bright enough to be photographed in this way appear every month.

EDWARD C. PICKERING.

February 20, 1899.

THE VARIABLE STARS U VULPECULAE AND ST CYGNI.[1]

THE variability of the stars $+20^\circ$ 4200 and $+28^\circ$ 3460 has been announced, and the designations U Vulpeculae and ST Cygni assigned to them by Professor Müller and Dr. Kempf of the Potsdam Observatory (*Astron. Nach.* **146**, 37). Measures of these stars have accordingly been made by Professor O. C. Wendell, with the photometer with achromatic prisms attached to the 15-inch equatorial of this Observa-

[1] *Harvard College Observatory Circular* No. 41.

tory. The star + 20° 4200 was compared with the star + 20° 4204, which is about 12.6′ distant. The results of these measures are shown by the heavy dots in Fig. 1, ordinates representing magnitudes, and abscissas, phases, or intervals in days since the last computed maximum. The measures made at Potsdam are represented by the light dots connected by lines, and the dotted line shows the light curve given in the article mentioned above. The results for + 28° 3460, which was compared with + 28° 3467, distant 15.0′, are similarly shown

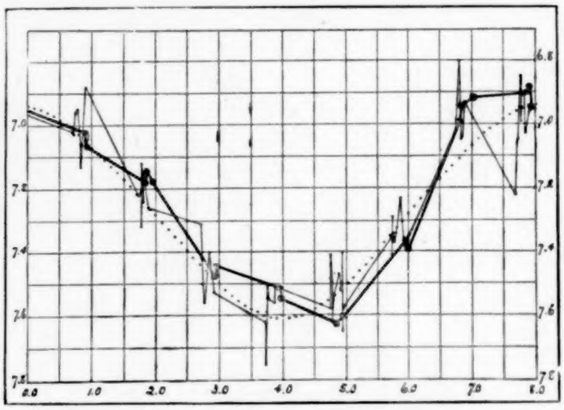


FIG. 1.

in Fig. 2. It will be seen that a smooth curve can be drawn, which would not differ on the average by more than one or two hundredths of a magnitude from the points observed here. The greater accordance of the Harvard measures as compared with those made at Potsdam, is partly due to the greater number of settings made each night, and partly to the smaller angular distance between the stars compared. At Cambridge, adjacent stars are compared directly, while at Postdam, each star is compared with the standard stars by means of an artificial star. In drawing the light curve of + 20° 4200, too great weight seems to have been given to the Potsdam observation for which the phase is 7.7^d, magnitude 7.22. Rejecting this, the other Potsdam observations agree closely with those made at Cambridge. To reduce the results to the same scale, the Cambridge magnitudes have been changed by + 0.16 and + 0.32, and the phases by + 0.8^d and — 0.2^d, in Figs. 1 and 2 respectively. This indicates that the period of + 20° 4200 is 7.98^d, instead of 8.00^d.

S ANTLIAE.

The accuracy attainable with the photometer described above is illustrated by the following observations of the variable star, S Antliae. This star has a period of $7^h\ 46.8^m$, which is the shortest known, except in the case of variables in clusters. In *Circulars* Nos. 23 and 25, it was shown that the period of U Pegasi, which was at one time supposed to be shorter than that of any other variable, should really be doubled. The alternate minima were bright and faint, the difference in magnitude amounted to 0.15 and was determined with a probable error but little exceeding one hundredth of a magnitude. It therefore appeared important to see if S Antliae belonged to the same class

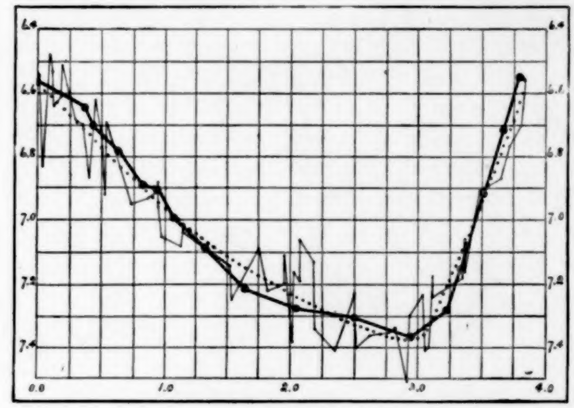


FIG. 2.

of variables, and if its period should be doubled. A series of measurements was accordingly made by Professor Wendell on different nights near the times of minima, care being taken that some of the minima should correspond to an odd, and others to an even number of periods of variation, E. The comparison star was -28° 7347, distant 21.8.′ A light curve was then formed from these measures, and residuals taken from it. On two nights E was odd, 11229 and 11349, and the means of the corresponding residuals were $+0.011$ and 0.000; on three nights E was even, 11306, 11340, and 11346, and the mean residuals were $+0.004$, -0.007, and $+0.008$. The assumed value of the difference in magnitude of S Antliae when at minimum and -28° 7347, was -1.676. Accordingly, the mean difference in magnitude

at minimum when E was odd, was -1.670, and when E was even, -1.674. It seems impossible that thousandths of a magnitude should have any real value, but if neglected, the accuracy of these observations would not be properly indicated. An error of two or three hundredths of a magnitude could not have failed to be detected. The variable star S Antliae, therefore, does not have a light curve resembling that of β Lyrae and U Pegasi, and the period of variation should not be doubled.

EDWARD C. PICKERING.

February 21, 1899.

A NEW STAR IN SAGITTARIUS.[1]

A NEW star appeared in the constellation Sagittarius early in the year 1898, or possibly in the latter part of the year 1897. It was found from the peculiarities of its spectrum, by Mrs. Fleming, during the examination of the Draper Memorial photographs. The approximate position for 1900, derived from a photographic chart, using the *Durchmusterung* positions of adjacent stars, is R.A. $= 18^h\ 56.2^m$, Dec. $= -13°\ 18'$. It was too faint to be photographed on eighty-seven plates, from September 5, 1888, to October 23, 1897, including three plates in 1888, one in 1889, three in 1890, eleven in 1891, three in 1892, twelve in 1893, ten in 1894, twenty-one in 1895, eight in 1896, and fifteen in 1897. On the last of these plates, A 2845, taken at Arequipa with the Bruce telescope, stars of the fifteenth magnitude are shown, but the Nova is invisible. The Nova appears on eight photographs taken in March and April 1898. In the description of them given below, the designation of the plate is followed by the date and the exposure. The letter B indicates that the photograph was taken at Arequipa with the 8-inch Bache telescope, and I, that it was taken at Cambridge with the 8-inch Draper telescope. Both of these instruments are doublets. The magnitudes are estimated by comparison with adjacent stars, and are approximate only, especially since the image was near the center of the plate only on B 21251, B 21258, and B 21319.

I 20428. March 8, 1898. Ex. 13^m. Magn. 4.7. Estimated 0.1 fainter than $-16°\ 5283$, photometric magn. 4.6.

I 20500. March 14, 1898. Ex. 13^m. Magn. 5.0. Estimated 0.5

[1] *Harvard College Observatory Circular* No. 42.

fainter than -16° 5283, and 0.4 brighter than -14° 5476, photometric magn. 5.6.

I 20612. April 3, 1898. Ex. 16^m. Magn. 8.2.

B 21251. April 19, 1898. Ex. 60^m. Magn. 8.2. An excellent photograph of the spectrum 3 mm in length, and showing the lines $H\beta$, $H\gamma$, $H\delta$, $H\epsilon$, $H\zeta$, $H\eta$, and probably $H\theta$, bright. A broad band, wavelength 4643, is also bright, and narrow bright lines are seen at about 4029, 4179, 4238, 4276, 4459, and 4536. These lines appear to be indentical with the corresponding lines found in the spectrum of Nova Aurigae. A well-marked dark line appears at 4060. It will be noticed that in this star, as in Nova Persei, Nova Aurigae, Nova Normae, and Nova Carinae, the line $H\epsilon$ is bright, while in variable stars of long period this line is always dark, being probably obscured by the broad calcium line H. This alone may serve to distinguish between a Nova and a variable. The accompanying dark lines on the edge of shorter wavelength of the bright lines in Nova Aurigae, Nova Normae, and Nova Carinae are not visible. The line K, also, is not shown.

I 20738. April 21, 1898. Ex. 9^m. Magn. 8.6.

B 21258. April 21, 1898. Ex. 62^m. Magn. 8.2. The spectrum closely resembles that on B 21251 taken two days earlier, but shows certain marked differences. The broad dark line at 4060 has disappeared, and a narrow bright line appears at 5005, doubtless identical with the principal nebular line, 5007. The hydrogen lines appear to be somewhat narrower and more intense than in the earlier photograph, although the lines in the adjacent stars are nearly the same in both.

B 21290. April 26, 1898. Ex. 10^m. Magn. 8.2.

B 21319. April 29, 1898. Ex. 10^m. Magn. 8.4.

The region of the Nova is included on two and perhaps three plates taken at Arequipa on October 7 and 8, 1898, but not yet received in Cambridge. They will later furnish important information regarding the rate of diminution of the light. On March 9, 1899, the morning after the discovery of the Nova, a faint image of it was obtained through passing clouds, which showed that its photographic image was about half a magnitude fainter than that of -13° 5193, magn. 9.5. On the morning of March 13, 1899, the Nova was examined visually by Professor O. C. Wendell. He found, first, that its position for 1900 is R.A. $= 18^h\ 56^m\ 12.2^s$, Dec. $= -13^\circ\ 18'\ 16''$. Secondly, that it was 1.52 magn. fainter than -13° 5200, and therefore 11.37 on the pho-

tometric scale. Thirdly, that its light was nearly monochromatic with a faint continuous spectrum. This Nova, therefore, like several that have preceded it, appears to have changed into a gaseous nebula. This is also indicated by the faint bright line at 5005, which, as stated above, appeared in the photograph of its spectrum taken April 21, 1898.

During the last four centuries fifteen stars have appeared which are commonly regarded as Novae. These stars are, in general, near the central line of the Milky Way. Their average galactic latitude is $11.2°$, while if uniformly distributed in the sky it would be $30°$. The region whose galactic latitude is less than $30°$ has an area equal to one half of that of the whole sky. Fourteen of these stars appeared in this region, and only one, Nova Coronae, outside of it. Nova Andromedae and Nova Centauri had spectra without bright lines, and unlike other Novae. Omitting them, the average galactic latitude of the other is $9.0°$. The galactic latitude of Nova Coronae is $46.8°$, and this seems to be the only known exception to the rule that all Novae having bright lines in their spectra have appeared near the central line of the Milky Way. Omitting this star, the average galactic latitude of the other twelve is $5.8°$. The only Novae known to have bright lines in their spectra are those which appeared in Corona, Cygnus, Perseus, Auriga, Norma, Carina, and Sagittarius. Omitting the first of these, the mean galactic latitude is $4.6°$. The probability that such a distribution is due to accident is extremely small.

EDWARD C. PICKERING.

March 14, 1899.

THE YERKES OBSERVATORY OF THE UNIVERSITY OF CHICAGO.

BULLETIN NO. 6.

PARALLAX OF THE ANDROMEDA NEBULA.

ATTENTION has recently been directed to the great nebula in Andromeda by reason of the announcement that a new star had appeared within it, at or near the position of the new star of 1885. Professor Barnard's observations of the nebula with the 40-inch refractor of this Observatory, which have been confirmed with the Lick telescope, as well as by photographs taken at the Harvard Observatory, show that the central parts of the nebula appear as usual, and that the nucleus must have been mistaken for a new star. At about the

time of the announcement Professor Barnard was engaged in an attempt to determine the parallax of the nebula from micrometric measurements with the 40-inch telescope of the position of the nucleus with reference to two comparison stars. On account of the exceptional brightness of the Andromeda nebula, and its great angular dimensions, any attempt to determine its distance is likely to be of general interest. Professor Barnard's preliminary results are accordingly given at the present time.

The mean results of the corrected measures of position angles and distances of the two small stars from the nucleus are as follows:

COMPARISONS WITH THE FIRST STAR.

In July and August, 1898 - - -	261.23°	124.70″
In November and December, 1898 - -	261.34	124.89

COMPARISONS WITH THE SECOND STAR.

In July and August, 1898 - - -	160.51°	228.42″
In November and December, 1898 - -	160.51	228.28

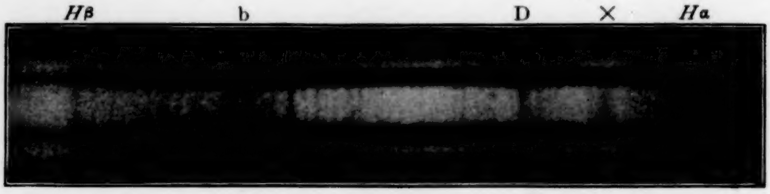
The differences between the first and last sets in each case are no greater than would be expected in the measurement of such an object, and are contrary in sign to what would be required if the nebula were nearer than the stars.

If it can be assumed that the comparison stars are in reality far beyond the nebula in space, the results would indicate that the distance of the nebula from the Earth is much greater than that of the nearest fixed star. As the stars are apparently in the nebula, and may in reality lie within its boundaries, such an assumption is, perhaps, hardly justifiable. The same objection, however, is applicable to any star in this region accessible to a large telescope. The great focal length of the 40-inch refractor, which so materially increases the precision of measures made with it, necessarily limits the choice of comparison stars to those lying within the immediate neighborhood of the nucleus.

THE SPECTRUM OF SATURN'S RINGS.

The strong absorption band in the red region of the spectrum of Saturn, the wave-length of which is given by Vogel as 6183, was seen by this observer to be absent, or extremely faint, in the spectrum of the rings. In 1889 Professor Keeler could detect no trace of the band in the spectrum of the rings with the Lick telescope (*A.N.*, 2927). An opportunity to test this point photographically presented itself last

August, through the courtesy of the International Color-Photo Co., of Chicago. The "Erythro" plates made by this company for the Yerkes Observatory are so sensitive in the red that photographs of the spectra of fifth magnitude stars extending down to $H\alpha$ have been secured with their aid. An "Erythro" plate was used by Mr. Ellerman in making the accompanying photograph of the spectrum of Saturn with the 40-inch telescope on August 18, 1898. At that time the planet was so far south and west in the early evening that a long



exposure could not be given. For this reason it was necessary to use the dispersion of only one 60° prism of dense flint, on the spectrograph of 1¼ inches aperture. The collimator objective has a focal length of 19 inches, and the camera lens employed on this occasion a focal length of 10½ inches. The slit, which was parallel to the planet's equator, was made rather wide (0.008 inch) in order to reduce the time of exposure. This accounts for the lack of sharpness in the photograph, which is enlarged seven and one-half diameters from the original negative.

Although the broad absorption band is clearly shown in the spectrum of the ball, no trace of it can be seen in the spectrum of the rings. The conclusion drawn from the visual observations, that the rings probably possess little or no atmosphere, is thus confirmed by the photograph.

The negative does not seem to show any of the bright lines mentioned by Lockyer (*A.N.*, 2881).

A photograph of the same region in the spectrum of Jupiter has recently been obtained here by Mr. Ellerman with the three-prism spectrograph. The absorption band is well shown, but its intensity is less than in the spectrum of the ball of Saturn. It is hoped that this photograph, as well as others of Saturn which will be made here with a dispersion of three prisms, will permit the wave-length of lines in the band to be accurately measured. GEORGE E. HALE.

MARCH 18, 1899.

Reviews.

Verification of the Ketteler-Helmholtz Dispersion Formulæ by Optical Constants of Solid Dyes. A. Pflüger, *Wied. Ann.*, **65**, 171–213, 1898.

Verification of Cauchy's Formulæ for Metallic Reflection by Optical Constants of Solid Cyanin. A. Pflüger, *Wied. Ann.*, **65**, 214–225, 1898.

The Anomalous Dispersion of Cyanin. R. W. Wood, *Phil. Mag.*, **281**, 380–385, 1898.

In the first paper Pflüger gives methods of experimentally determining the coefficient of absorption k, and the refractive index n, of solid fuchsin and cyanin inside regions of strong absorption, and shows that these values of k and n satisfy the Ketteler-Helmholtz dispersion formulæ

$$n^2 - k^2 - 1 = \sum \frac{D\lambda^2 (\lambda^2 - \lambda_m^2)}{(\lambda^2 - \lambda_m^2)^2 + g^2 \lambda^2}$$

$$2\,n\,k = \sum \frac{D\,g\,\lambda^3}{(\lambda^2 - \lambda_m^2)^2 + g^2 \lambda^2}.$$

The coefficient k is obtained by measuring with a König's spectral photometer the absorption by thin films of the dyes deposited from alcoholic solutions on glass plates. For strongly absorbing regions, films of from 142 $\mu\mu$ to 238 $\mu\mu$ thickness were used, and the thickness determined by comparing the interference line spectrum from one film with the displaced spectrum from a second.

Values of n within absorption bands were computed from measurements of the linear separation of the two images of photographed iron lines, produced by a solid double prism of small angle (80″ to 120″) obtained by evaporating alcoholic solutions between a glass tube of small curvature and a glass plate.

Since direct substitution in the formulæ is not possible, Pflüger has recourse to the method used by Ketteler in his work on alcoholic solutions of cyanin.

The dispersion formulæ are written

$$\begin{cases} X = \left(n^2 - k^2 - a - \dfrac{b}{\lambda^2} + c\,\lambda^2\right)\dfrac{1}{\lambda^2} = \sum \dfrac{D(\lambda^2 - \lambda_m^2)}{(\lambda^2 - \lambda_m^2)^2 + g^2\lambda^2} = \Phi(\lambda^2) \\ Y = \dfrac{m\,k}{\lambda^3} = \sum \dfrac{D\,g}{(\lambda^2 - \lambda_m^2)^2 + g^2\lambda^2} = F(\lambda^2) \end{cases}$$

$Y = \dfrac{m\,k}{\lambda^3}$ is plotted with Y and λ^2 as coördinates. This is broken up into seven symmetric component curves, each corresponding to a term in the summation; from these subsidiary curves the constants λ_m^2, D, g are deduced, the two curves

$$X = \left(n^2 - k^2 - a - \frac{b}{\lambda^2} + c\,\lambda^2\right)\frac{1}{\lambda^2}$$

$$X = \sum_{m=1}^{7} \frac{D(\lambda^2 - \lambda_m^2)}{(\lambda^2 - \lambda_m^2)^2 + g^2\lambda^2}$$

are plotted with X and λ^2 as coördinate, and compared. The agreement is found to be well within experimental error except in the red, where theory demands larger values of k or smaller values of n.

In his second paper Pflüger compares values of n and k obtained by the direct method above with those deduced from

$$n_h^2 - k_h^2 = \tan^2 h$$

$$k_h^2 = \sin^2 h \cdot \tan^2 h \cdot \left[1 - \tan^2\left(\frac{\pi}{4} - \alpha_h^{\cdot}\right)\right]$$

by measuring h, the angle of incidence, and $\alpha_h^{\cdot}$, the emergent azimuth of light initially plane polarized at azimuth of 45° and twice reflected from two parallel plates of the solid dye.

For solid cyanin the agreement is so good, especially in the green, that he concludes the verification of the above equations, and hence, indirectly, Cauchy's formulæ for metallic reflection, from which they are derived.

In a supplement to the first paper, he points out that in the red the values of n agree, while those for k, determined by this indirect method, are larger than those given by the direct, as the theory required; using these corrected values he finds the Ketteler-Helmholtz formulæ verified throughout the visible spectrum.

In the paper by Wood, cited above, is given a method of preparing solid prisms of the dyes, of fairly large angles (10′ to 15′) and approximately perfect optical surface. Wood fused the dye and pressed it out

into a thin wedge between two pieces of plate glass, afterward knocking off one of the glass faces. He produced solid cyanin prisms of from 10′ to 15′ angle, and obtained a very perfect dispersion curve outside the absorption band. Inside this his prisms were too thick to transmit sufficient light.

On the red side of the band his curve agrees very well with Pflüger's, while on the blue side it runs lower, possibly due to change in the optical properties of cyanin by fusion.

G. O. James.

Johns Hopkins University.
February 3, 1899.

ERRATA.

In Mr. Wright's article in this Journal, Vol. IX, p. 65, line 9, for

$$\delta\omega = + 3.12 \quad \pm 0.65 \quad \pm 1.95 \text{ (radians).}$$

read

$$\delta\omega = + 0.0545 \quad \pm 0.0113 \quad \pm 0.0340 \text{ (radians).}$$

Index page of the same number (February), for the Orbit of ζ Aquilae, read the Orbit of η Aquilae.

NOTICE.

The scope of the ASTROPHYSICAL JOURNAL includes all investigations of radiant energy, whether conducted in the observatory or in the laboratory. The subjects to which special attention will be given are photographic and visual observations of the heavenly bodies (other than those pertaining to "astronomy of position"); spectroscopic, photometric, bolometric and radiometric work of all kinds; descriptions of instruments and apparatus used in such investigations; and theoretical papers bearing on any of these subjects.

In the department of *Minor Contributions and Notes* subjects may be discussed which belong to other closely related fields of investigation.

Articles written in any language will be accepted for publication, but unless a wish to the contrary is expressed by the author, they will be translated into English. Tables of wave-lengths will be printed with the short wave-lengths at the top, and maps of spectra with the red end on the right, unless the author requests that the reverse procedure be followed. If a request is sent *with the manuscript* one hundred reprint copies of each paper, bound in covers, will be furnished free of charge to the author. Additional copies may be obtained at cost price. No reprints can be sent unless a request for them is received before the JOURNAL goes to press.

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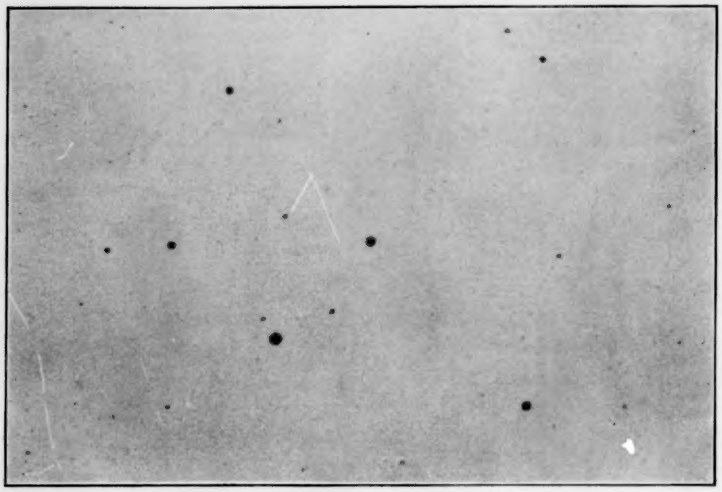
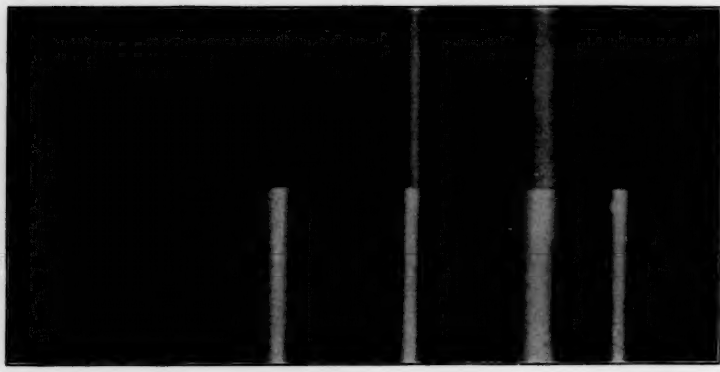
PLATE III.



NOVA SAGITTARII.
B 21319. April 29, 1898. Ex. $1c^{m}$.

B 21251 April 19, 1898



B 21258 April 21, 1898

SPECTRA OF NOVA SAGITTARII.
Photographed at the Harvard College Observatory, Arequipa, Peru.